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FLOOD PLAIN INFORMATION

ONTONAGON RIVER
ONTONAGON, MICHIGAN
AND
LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN

PREPARED IN COOPERATION
with
WATER RESOURCES COMMISSION
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
THE VILLAGE OF ONTONAGON
and
ONTONAGON COUNTY
by
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
SEPTEMBER 1970

Michigan. Dept. of Natural Resources. Water Resources Comm.

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS

FLOOD PLAIN INFORMATION ON

ONTONAGON RIVER
ONTONAGON, MICHIGAN

AND
LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN

ST. PAUL, MINNESOTA
SEPTEMBER 1970

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION,
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO, ILLINOIS 60605

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22 August 1973

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Mr. Robert Knecht
Office of Coastal Zone Management
National Oceanic and Atmospheric Administration
Rockville, Maryland 20850

Dear Bob:

Here is a copy of the U. S. Army Corps of Engineers Flood Plain Information Report on Ontonagon, Michigan, which I described to you at the Great Lakes Basin Commission Meeting at St. Clair. I hope this example will help as you proceed with your important work of implementing the Coastal Zone Management Act of 1972.

It was a pleasure to meet you. Please call me if the Corps of Engineers can be of any help with Coastal Zone Management matters on the Great Lakes.

Sincerely,

1 Incl
As stated

ERNEST GRAVES
Major General, USA
Division Engineer

CE

August 27, 1973

Major General Ernest Graves
Corps of Engineers
536 South Clark Street
Chicago, Illinois 60605

Dear Ernie:

Thank you very much for sending me the flood plain information report on Ontonagon, Michigan. Based on a quick perusal, the report is going to prove very useful as we plan for the implementation of the coastal zone management program in the Great Lakes area.

Perhaps we can discuss the matter further when we meet at the next Commission meeting in late November.

With best personal regards,

ORIGINAL SIGNED BY
R. W. KNECHT

Robert W. Knecht
Director
Office of Coastal Environment

CC:C-1 W/Report

RWKNECHT:bp

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INTRODUCTION

This report relates to the flood situation along the Ontonagon River in the vicinity of Ontonagon, Michigan, and beach erosion along Lake Superior for the Ontonagon County, Michigan, shoreline. Prepared at the joint request of the Ontonagon Village Council and the Ontonagon County Board of Supervisors through the Water Resources Commission, Michigan Department of Natural Resources, this document will aid in the solution of local flood and shoreline erosion problems and in the best utilization of the affected land. The report is based upon information on rainfall, runoff, historic and current flood heights, and other technical data bearing upon the occurrence and size of floods in the Ontonagon area. Lake levels, wave heights, past and present erosion trends, and other pertinent information are factors used in determining the rate and extent of shoreline erosion along Ontonagon County.

Elevations given in this report refer to IGLD (International Great Lakes Datum 1955) which is mean water level at Father Point, Quebec. Two other datum planes are in common use for the area. These are:

Mean Sea Level USGS and USC & GS Datum
Lake Superior Low Water Datum

The latter is used to correlate soundings on U. S. Lake Survey Charts and for shore structures used for navigational or coast protection purposes, while the former is the basis of the national vertical control established by the Coast and Geodetic Survey and used for U. S. Geological Survey mapping.

The relationship between these three principal datum planes for Lake Superior is given on Figure 1.

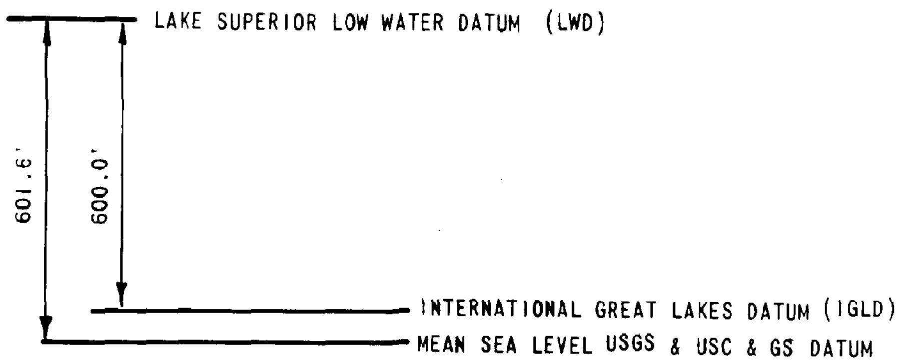


Figure 1. -- RELATIVE DATUM PLANES

Two significant phases of the Ontonagon flood problem are covered in the report. First, records of the largest known floods of the past on the Ontonagon River are assembled. Secondly, probable future floods designated as Intermediate Regional Floods and Standard Project Floods are analyzed. Intermediate Regional Floods have an average frequency of occurrence on the order of once in 100 years as determined from an analysis of known floods on the Ontonagon River, with consideration given other streams which have similar physical characteristics and are in the same general geographic region. Standard Project Floods are of rare occurrence and on most streams are considerably larger than any floods that have occurred in the past.

In problems concerned with the control of developments in the flood plains of the Ontonagon River, and in reaching decisions on the size of floods to consider for this purpose, appropriate consideration should be given to the possible future occurrence of floods of the size of those that have occurred in the past, the Intermediate Regional Floods, and the Standard Project Floods.

A record of shoreline erosion along Ontonagon County has been compiled covering the past 110 years. From this information and an analysis of lake and shoreline characteristics, the extent of future erosion has been projected for the year 2020. This data will be useful in the regulation of new developments along the Lake Superior frontage. Also, the need for protective measures to guard against future shoreline erosion can be evaluated.

The report contains maps, profiles, and cross sections which indicate the extent of flooding which has been experienced and which might occur in the future in the vicinity of Ontonagon. Beach cross sections and maps showing the outline of the past and projected future Lake Superior shoreline changes are also included. These plates should prove helpful in planning the best use of the affected areas. Floor levels for buildings may be planned high enough to avoid flood damage, and developments may be located far enough from the lake to protect against anticipated erosion. Buildings that are located at lower elevations or closer to the lake will do so with recognition of the chance and hazards of possible damage.

Plans for the solution of flood and erosion problems are not included herein. Rather, the report is intended to provide the basis for further study and planning on the part of Ontonagon County and the Village of Ontonagon in arriving at solutions to minimize vulnerability to damages. This might involve local planning programs for controlling the type of use made of the flood plain and lake frontage through zoning and subdivision regulations, the construction of flood protection and erosion control works, or a combination of the two approaches.

The St. Paul District of the Corps of Engineers will provide, upon request, technical assistance to the federal, state, and local agencies in the interpretation and use of the information contained herein.

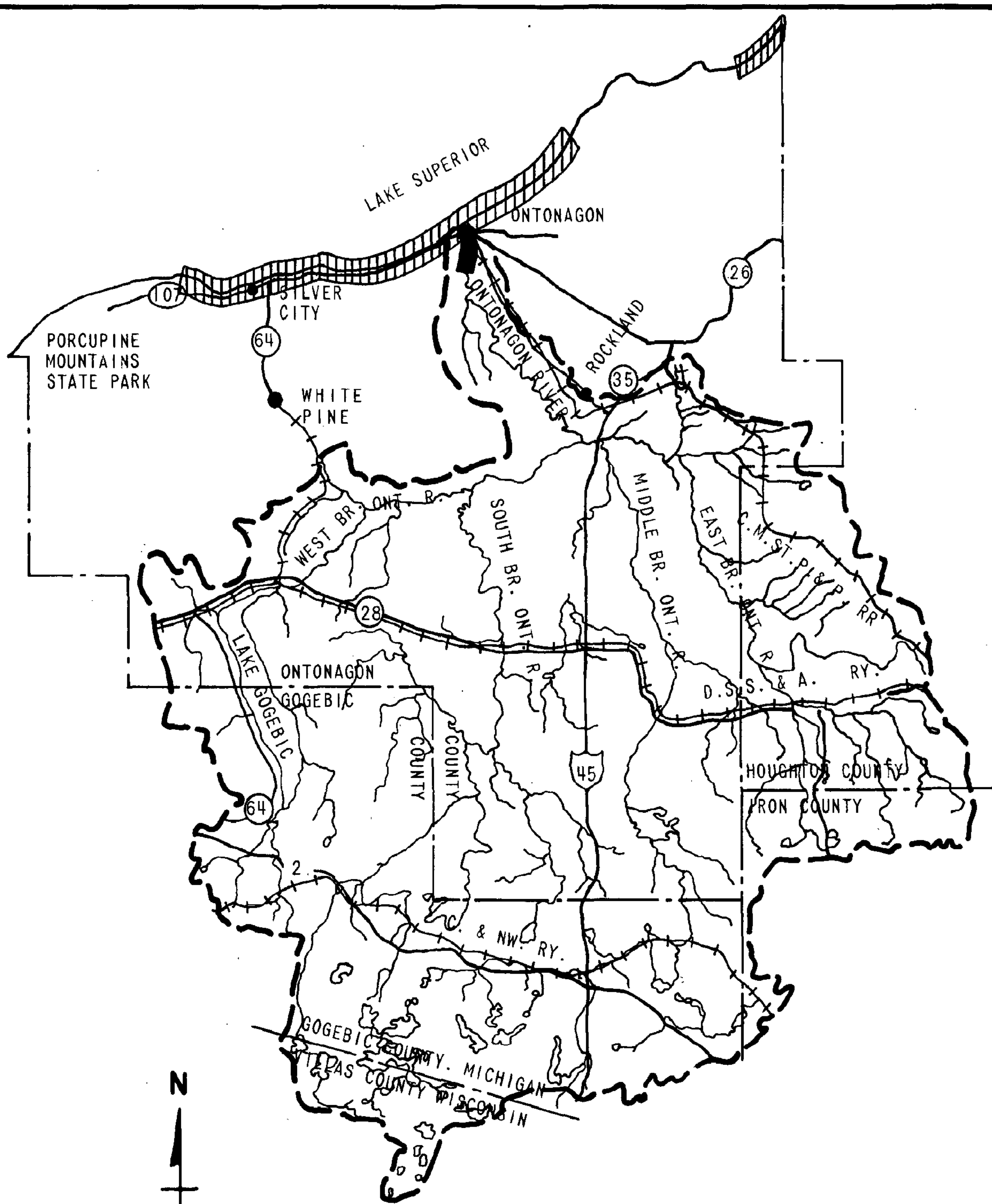
SUMMARY OF FLOOD PLAIN AND SHORE EROSION SITUATION

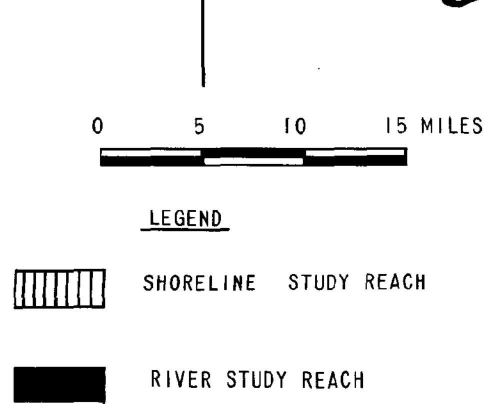
Ontonagon County is located on the upper penninsula of Michigan along the south shore of Lake Superior. Lake frontage in this area is experiencing recreational developments at various locations and residential, commercial, and industrial growth in and near the Village of Ontonagon and at other smaller communities.

The Village of Ontonagon is located on the south shore of Lake Superior at the mouth of the Ontonagon River. Most of the village is established along the east side of the Ontonagon River with mainly industrial development along the west bank. Location of the Ontonagon River and its drainage basin is shown on Plate 1.

The principal residential development of Ontonagon is located on high ground east of the Ontonagon River, a substantial distance from Lake Superior. There are, however, considerable residential and, particularly, commercial areas which are vulnerable to serious flooding. Portions of this land have been inundated by floods of the past and a substantially greater area is within reach of the potentially greater floods of the future. Much of the Ontonagon County shoreline has been seriously damaged by past erosion, and considerably greater damage may be expected in the future. The only areas which have been exempt from extensive erosion have stable rock frontages adjoining Lake Superior. Some examples include the Porcupine Mountains, Gull Point, Ten-Mile Point, Fourteen-Mile Point, and Wolf Point.

The U. S. Geological Survey has maintained a stream gaging station on the Ontonagon River near Rockland, Michigan, since June 1942. Records are also available on the tributaries to the Ontonagon River for a comparable period. No official flow records have been maintained on the Ontonagon River at Ontonagon due to poor stage-discharge relationships caused by lake stage and ice conditions. A staff gage





DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

WATERSHED MAP

ONTONAGON RIVER
ONTONAGON, MICHIGAN
AND
LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN

SEPTEMBER 1970

PLATE 1

is located at Ontonagon to give instantaneous readings of Lake Superior levels. Official Lake Superior levels have been recorded at Marquette, Michigan, since 1860.

Residents along the Ontonagon River and Lake Superior have been interviewed and newspaper files and historical documents searched for information concerning past floods and erosion history. From these investigations and from studies of possible future floods on the Ontonagon River and future shore erosion along Lake Superior, the local flood and shore erosion situation, both past and future, has been developed. The following paragraphs summarize the significant findings which are discussed in more detail in succeeding sections of this report.

* * *

THE GREATEST FLOOD known on the Ontonagon River occurred in April 1963. The river reached a record flood level which was about two feet above any previous flood. Ice floes from the river combined with windrowed lake ice to form an ice jam at the river mouth. Ice jams were also experienced at the State Highway 64 and railroad bridges with resultant flooding in the lower areas of Ontonagon.

* * *

THE GREATEST RECORDED DISCHARGE on the Ontonagon River was gaged at 42,000 cubic feet per second (cfs) at the Rockland gage on August 22, 1942. Extensive flooding occurred in the vicinity of Ontonagon as a result of this summer storm.

* * *

OTHER KNOWN FLOODS occurred in 1912, 1922, and 1923, although there are few details available on these floods relative to stage and discharge.

* * *

INTERMEDIATE REGIONAL FLOODS on the Ontonagon River have an average frequency of occurrence of once in 100 years. In this study, the Intermediate Regional Flood level was determined from an analysis of past flood occurrences on the Ontonagon River which were caused by ice jams, high discharges, or a combination of the two events. The analysis shows that the Intermediate Regional Flood would be about 0.5 feet higher than the April 1963 flood of record.

* * *

STANDARD PROJECT FLOOD determinations are based on a 1.5-foot increase above the 1963 stage, or about 1.0 foot above the Intermediate Regional Flood stage. A discharge for the Standard Project Flood was not determined. Due to the significant effects of ice jams in the harbor entrance and the lack of data to establish an accurate open water rating curve, a Standard Project Flood stage, based on a vertical distance above the Intermediate Regional Flood stage, appears to be more practicable than attempting to develop a Standard Project Flood discharge and estimating a stage at Ontonagon corresponding to that flow.

* * *

FLOOD DAMAGES that would result from recurrence of major known floods would be substantial. Even greater damages would occur during an Intermediate Regional Flood or a Standard Project Flood because of the greater depth and wider extent of flooding. Extensive localized flood damage may result from unpredictable ice jams or intensive storm runoff for small areas.

* * *

MAIN FLOOD SEASON for the Ontonagon River is usually in the spring of the year when the heavy accumulation of winter snow melts rapidly during a prolonged period of above freezing temperatures. Rapid spring runoff following a severe winter tends to break up the river ice cover and cause ice jams at bridges and at other restrictions in the channel. One known flood, in August 1942 was caused by heavy rainfall.

* * *

FLOOD DURATIONS depend primarily on the severity of the ice jams in the harbor entrance and the unpredictable time for release of the jam. In 1963 the flooding was experienced for about a 24-hour period before the ice jam suddenly released and stages dropped.

* * *

HAZARDOUS CONDITIONS would occur during large floods as a result of the ice jams, rapidly rising streams, and deep flows.

* * *

FUTURE FLOOD HEIGHTS that would be reached if the Intermediate Regional and Standard Project Floods occurred in the vicinity of Ontonagon are shown in Table 1. The table gives the comparison of these flood crests and also shows the comparison with the April 1963 flood of record.

TABLE 1

RELATIVE FLOOD HEIGHTS

Flood	Location	River Miles	Estimated Peak Discharge cfs	Above April 1963 Flood feet
August 22, 1942	State Hwy. 64	0.66	43,000*	Unknown
April 1, 1963			18,200*	---
Intermediate Regional			38,000	0.5
Standard Project			---	1.5

*Estimated from stream gaging records on Ontonagon River at Rockland, Michigan.

* * *

A DISASTROUS STORM occurred on Lake Superior in November 1913 which was described as the most intense on record. Shoreline erosion damage was not believed to be too intense, although many lives were lost at sea during the storm. The main reason for the minimal erosion was the relatively low lake level maintained at that time.

* * *

ANOTHER INTENSE STORM occurred in December 1968 during a period of high lake levels. Damage from the storm included losses of up to 50 feet of shoreline at some locations along Ontonagon County.

* * *

DAMAGE FROM HIGH LAKE LEVELS occurred in the period from 1950 through 1952. During one 12-month interval erosion caused losses of up to 50 feet in depth from lots, many of which contained houses and cabins. About 100 homes and cabins along the Ontonagon County shoreline were destroyed or had to be moved.

* * *

THE EXTENT OF EROSION BY THE YEAR 2020 has been projected for the Ontonagon County shoreline along Lake Superior. The projected 2020 shoreline outline was determined from an analysis of past erosion occurrences along Lake Superior which were caused by intense storms, high lake levels, or a combination of the two events. The analysis shows that losses due to erosion may be as much as 150 feet of shoreline within the next 50 years.

* * *

SEASONAL VARIATIONS in lake levels occur each year. Normally, the highest levels are experienced in August or September; however, localized storms may cause high levels of short duration any time during the year.

PAST FLOODS

This section of the report is a history of floods on the Ontonagon River in the vicinity of Ontonagon, Michigan. The Village of Ontonagon is located in Ontonagon County, along the south shore of Lake Superior at the mouth of the Ontonagon River. The portion of the Ontonagon River studied extends from the mouth upstream 3.5 river miles to the S-curve approximately 0.7 miles south of the Ontonagon Village limits. River mileage is measured from the outer end of the west pier at the Ontonagon Harbor where the drainage basin area is 1,390 square miles. There are no tributaries of significance within the study reach of the Ontonagon River; however, there are four main branches above Rockland, Michigan.

The U. S. Geological Survey has not maintained flow records at Ontonagon due to poor stage-discharge relationships caused by lake stage and ice conditions. A stream gaging station has been in operation on the Ontonagon River at Rockland, Michigan, since June 1942. Data from Rockland has been reviewed and applied in the absence of a station at Ontonagon.

Searches of flood history have developed information on the Ontonagon River and the area in and near the Village of Ontonagon. The earliest known flood occurred in 1912, although no details are available relative to stage and discharge. Other floods are discussed in detail later in this report.

ONTONAGON RIVER

Settlement

The earliest settlers in the Ontonagon area were fur traders. In the French regime of 1634 to 1759, through the time of British control from 1759 to 1814, and up to 1840 under American rule, fur trading was the major factor influencing settling efforts. By 1880, fur trading had ended and was replaced by copper and silver mining.

Copper mining started in 1845 and experienced a "boom" period until 1870. Ontonagon County population grew from 380 to 5,400 during this period. A photograph showing the development in Ontonagon in about 1865 is shown as Figure 2. After the big boom period, copper mining was carried on by individuals and reorganized companies until 1918 when most of the settlements closed. In 1950 the White Pine Copper Company began development of a new mine at White Pine. In 1966 the operations expanded to provide employment for over 1,600 people.

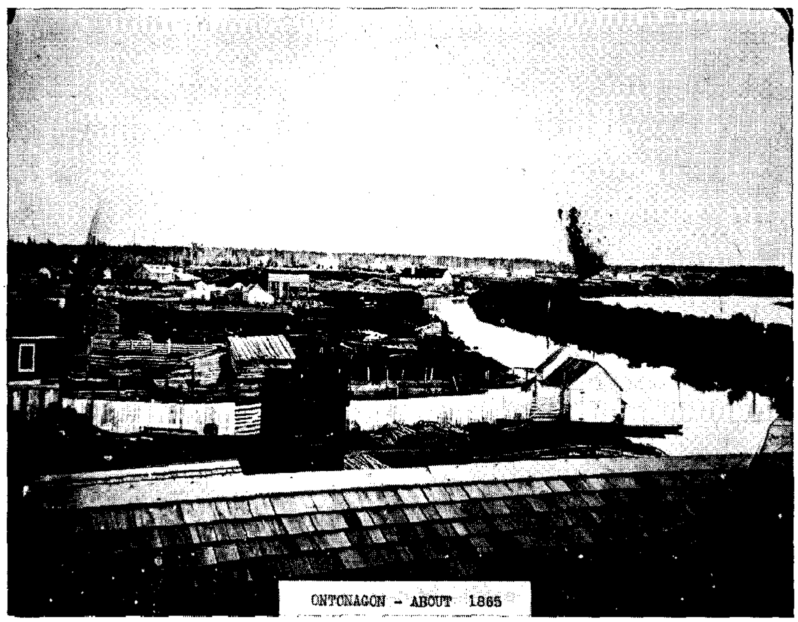


Figure 2. -- ONTONAGON IN ABOUT 1865

Silver was mined in the period from 1873 to 1876. Although silver mining was never profitable, it was a contributing factor to population growth.

Lumbering played an important part in the economic development of the area. From 1880 to 1900, pine was extensively harvested. After the pine era, hardwood and hemlock were cut. Some was sawed into lumber locally but much of it was shipped to other mills by rail.

When activity in copper mining declined due to price of copper and cost of mining, and when the forests were worked out, farming became a means of livelihood.

The economy of Ontonagon today is based on tourism, farming, and industry and supports a village population of 2,360 (1970 population). Ontonagon County reports a total population of 10,335. Major industries in the area include manufacture of paperboard and the mining and refining of copper.

Flood Damage Prevention Measures

In accordance with Section 205 of the 1948 Flood Control Act, as amended, a reconnaissance investigation was conducted and a brief report prepared for the Village of Ontonagon in 1963. Two plans of local protection were studied. Plan 1 included a levee about 4,000 feet long located on the right bank starting just upstream of the Chicago, Milwaukee, St. Paul, and Pacific (C.M.St.P.&P.) Railroad Bridge with the necessary closure structure and interior drainage facilities. Plan 2 consisted of a continuous levee on the right bank similar to Plan 1 and, in addition, would provide a 300-foot wide diversion channel extending from a point upstream of the C.M.St.P.&P. Railroad Bridge to Lake Superior, a distance of about 6,000 feet. The diversion channel would provide direct access to the lake for by-passing excessive flows or to provide relief from high stages caused by ice jams at bridges or in the harbor entrance. Both plans were designed to provide protection against the 100-year flood, but neither plan was economically feasible based on a benefit cost analysis and construction was not recommended.

Flood Warning and Forecasting Services

The Ontonagon River basin does not lie within an area served by Environmental Science Services Administration (ESSA) river forecast centers and therefore no official river stage predictions are made. However, as high discharges are experienced at upstream locations the information is made available to Ontonagon and unofficial predictions of impending flood stages are made by local village officials.

The Stream and Its Valley

The Ontonagon River drains 1,390 square miles of a relatively rough, wooded, and sparsely populated area of northwest Michigan and northeast Wisconsin. Most of the drainage area consists of well defined valleys, but near Lake Superior the river meanders through a broad, gently sloping plain. The upper basin is bowl shaped with four tributaries: the East Branch Ontonagon River, Middle Branch Ontonagon River, South Branch Ontonagon River, and West Branch Ontonagon River. Plate 1 shows the watershed and stream drainage system for the Ontonagon River.

The total fall in the Ontonagon River from its headwaters to the mouth at Lake Superior is approximately 1,100 feet. The average gradient is 2.2 feet per mile in the lower reach from Rockland to the mouth. In the upper reaches, the tributaries flow through various lakes but, in general, the gradient is relatively steep. Lake Gogebic is the largest inland lake in the basin covering an area of over 20 square miles. The outlet of Lake Gogebic is the West Branch of the Ontonagon River, which together with the South Branch flow into the impounded waters of the Vicoria Hydro-Electric Power Dam operated by the Upper Peninsula Power Company. Drainage areas in the Ontonagon River basin are shown in Table 2.

TABLE 2

DRAINAGE AREAS IN WATERSHED OF ONTONAGON RIVER

Stream	Location	Drainage Area Sq. Mi.
Ontonagon River	Ontonagon	1,390
Ontonagon River	Near Rockland	1,340
Ontonagon River, Cisco Branch	Cisco Lake Outlet	51
Ontonagon River, East Branch	Near Mass	272
Ontonagon River, Middle Branch	Near Paulding	190
Ontonagon River, Middle Branch	Near Rockland	671
Ontonagon River, Middle Branch	Near Trout Creek	203
Ontonagon River, South Branch	Near Even	348
Ontonagon River, West Branch	Near Bergland	162

The Ontonagon River passes through the coastal plain in a wide valley which extends nearly 5 miles inland from the mouth of the river. Width of the flood plain varies from 1,000 feet near Riverside Cemetery to 6,500 feet at the upper study limits. Areas inundated by a severe flood such as the Standard Project Flood would extend to substantial distances within the commercial and residential areas of Ontonagon.

Developments in the Flood Plain

Plate 8 is an index map of the three sheets that show the flooded areas of the Ontonagon River during the Intermediate Regional and Standard Project Floods. Plates 9 through 11 show the flood plain of the Ontonagon River for the reach covered by this report.

Some new commercial areas are being and have been established within the flood plain in Ontonagon. Some well established residential, commercial, and industrial areas within the village limits also fall within the flood plain limits. Upstream from the urban development of Ontonagon, most of the flood plain is devoted to forestry or agricultural purposes.

The C.M.St.P.&P. Railroad serves Ontonagon from the southeast. Portions of the main line and spur tracks within the village limits are in the flood plain of the Ontonagon River.

U. S. Highway 45, which connects Ontonagon with Rockland to the southeast, is located out of the flood plain of the Ontonagon River. Michigan State Highway 64 is the only connection between Ontonagon and the Lake Superior shoreline to the west. Portions of this route have been inundated by past floods and would be subject to even greater flooding during the Intermediate Regional and Standard Project Floods.

Several structures in the flood plain of the Ontonagon River have been damaged by past floods and the potential for further damage is considerably greater. The Standard Project Flood would cause considerable damage to many additional buildings including residences, commercial establishments, industrial operations, and bridges.

Bridges Across the Stream

Within the reach covered by this study, there are two bridges across the Ontonagon River. Table 3 lists pertinent elevations for the structures and shows their relation to the crest of the flood of April 1, 1963, and the Intermediate Regional Flood. Figure 3 shows photographs of these bridges.

Michigan State Highway 64 crosses the river at Mile 0.66 with a 309-foot long bridge. There is a draw span over the main channel

TABLE 3

BRIDGES ACROSS ONTONAGON RIVER

Miles Above Mouth	Identification	Stream Bed Elev. feet	Floor Elev. feet	Intermediate Regional Flood Crest Elev. feet	April 1963 Flood Crest Elev. feet	Low Steel Elev. feet	Low Steel Above 1963 Flood feet	Low Steel Below Int. Reg. Flood feet
0.66	State Highway 64	579.5	613.1	607.9	606.9	607.9	1.0	---
1.08	C.M.St.P.&P.RR	583.0	612.0	607.9	606.9	607.2	0.3	0.7

NOTE: Flood crests do not include ice cover.

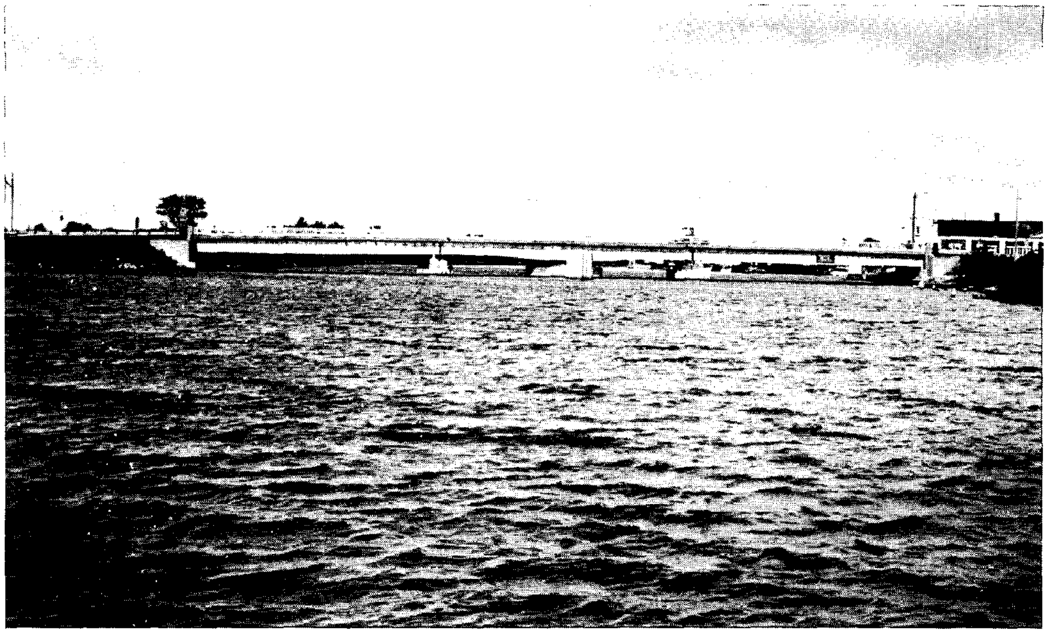


Figure 3. -- ONTONAGON RIVER BRIDGES

Upper view is upstream side of State Highway 64 Bridge over the Ontonagon River at Mile 0.66. Lower view is upstream side of C.M.St.P.&P. Railroad Bridge over the Ontonagon River at Mile 1.08.

with horizontal clearance of 30.5 feet for the east opening and 31.5 feet for the west opening. The end spans are fixed with a clear height of 7.8 feet above low water datum. Both approaches to the bridge are low and would be inundated by the Intermediate Regional and Standard Project Floods as they were in April 1963.

About 2,200 feet above the highway bridge, a C.M.St.P.&P. Railroad Bridge crosses the Ontonagon River. This bridge has two spans over the main channel which are 108 feet and 100 feet in length with a 9.4-foot clear height above low water datum. There is no draw span in this bridge which has a total length of 554 feet. During the Intermediate Regional and Standard Project Floods water would be above the low steel of the end spans.

Obstructions to Flood Flow

Obstructions to flood flow are mainly due to the two bridges discussed previously. During periods of spring snow and ice melt, ice tends to pile up behind the bridges seriously affecting the discharge capacity of the river. As the ice breaks up in Lake Superior the problem becomes more intense. "Windrows" of ice, running parallel to the shoreline, are formed which choke off the normal release of river water to the lake. This situation has been characteristic of all of the spring floods on record.

FLOOD SITUATION

Flood Records

No records of river stages are maintained at Ontonagon due to a poor stage-discharge relationship caused by lake stage and ice conditions. A stream gaging station upstream from Ontonagon at Rockland, Michigan, has been in operation since June 1942. Records from this station have been used in the absence of data at Ontonagon.

To supplement the records obtained at Rockland, local residents were interviewed for information on dates and heights of past floods. Newspaper files, historical documents, and records were searched, and reports of field investigations concerning floods were reviewed. This information has been used to develop a history of floods in the Ontonagon area covering the past 60 years.

Flood Stages and Discharges

Table 4 lists the maximum annual discharge and the associated high water stage for the Ontonagon River at Rockland. Maximum annual stages caused by ice jams are also reported when they exceed the stage which occurred during maximum discharge.

The greatest known flood in the Village of Ontonagon occurred on April 1, 1963. Ice floes from the river combined with windrowed lake ice to create ice jams at the mouth of the Ontonagon River and at the State Highway 64 and C.M.St.P.&P. Railroad Bridges. Elevations of 1963 high water marks in Ontonagon have been determined and are presented on the profile drawing (Plate 12).

TABLE 4

ONTONAGON RIVER NEAR ROCKLAND, MICHIGAN

MAXIMUM ANNUAL DISCHARGES AND STAGES

1942 - 1967

The table includes maximum annual discharge and stage data for the Ontonagon River near Rockland, Michigan. Drainage area = 1,340 square miles. Datum of gage = 637.12 feet, IGLD.

Year	Maximum Discharge During Year cfs	Date	Maximum Stage feet	Crest Elevation feet
1942	42,000	Aug. 22, 1942	28.60	665.72
1943	12,600	May 6, 1943	15.70	652.82
Max. stage due to ice jam		Apr. 2, 1943	20.00	657.12
1944	12,600	Jun. 5, 1944	15.69	652.81
1945	12,800	May 22, 1945	15.80	652.92
Max. stage due to ice jam		Mar. 16, 1945	16.30	653.42
1946	17,600	Jun. 24, 1946	18.48	655.60
1947	No Record	Apr. 6, 1947	20.84	657.96
1948	6,600	Apr. 11, 1948	11.85	648.97
Max. stage due to ice jam		Mar. 26, 1948	13.11	650.23
1949	17,900	Jul. 6, 1949	18.52	655.64
1950	14,700	May 6, 1950	16.73	653.85
Max. stage due to ice jam		Apr. 17, 1950	20.11	657.23
1951	16,500	Jun. 24, 1951	17.72	654.84
1952	18,400	Apr. 19, 1952	18.78	655.90
1953	19,500	Aug. 4, 1953	19.38	656.50
1954	16,300	Apr. 26, 1954	17.65	654.77
1955	14,300	Sep. 17, 1955	16.50	653.62
Max. stage due to ice jam		Apr. 2, 1955	18.05	655.17

TABLE 4 (Continued)

Year	Maximum Discharge During Year cfs	Date	Maximum Stage feet	Crest Elevation feet
1956	12,000	Apr. 4, 1956	No Record	
1957	14,300	Apr. 20, 1957	16.48	653.60
1958	9,460	Apr. 14, 1958	13.56	650.68
1959	8,830	Apr. 8, 1959	13.14	650.26
1960	22,400	Apr. 24, 1960	20.82	657.94
1961	11,800	Mar. 28, 1961	14.80	651.92
Max. stage due to ice jam		Mar. 27, 1961	19.48	656.60
1962	7,520	May 2, 1962	12.11	649.23
Max. stage due to ice jam		Mar. 29, 1962	13.87	650.99
1963	17,700	Apr. 1, 1963	17.49	654.61
Max. stage due to ice jam		Mar. 30, 1963	18.81	655.93
1964	18,500	Apr. 13, 1964	17.74	654.86
1965	13,300	May 9, 1965	15.07	652.19
Max. stage due to ice jam		Apr. 11, 1965	21.01	658.13
1966	17,800	Mar. 18, 1966	16.97	654.09
Max. stage due to ice jam		Mar. 16, 1966	20.68	657.80
1967	17,600	Mar. 31, 1967	16.90	654.02
Max. stage due to ice jam		Mar. 31, 1967	18.66	655.78
1968	15,400	Mar. 19, 1968	15.97	653.09

The largest known discharge on the Ontonagon River at Ontonagon occurred on August 22, 1942. While flooding was experienced during this period of high flow, it was not as severe as the 1963 flood. During the 1942 flood, the discharge at Ontonagon was not gaged; however, at Rockland the peak flow was 42,000 cfs.

Flood Occurrences

In addition to the previously mentioned floods of 1942 and 1963, other known floods occurred in Ontonagon in 1912, 1922, and 1923. Few details relative to stage and discharge are available for these high water periods.

Since floods in Ontonagon occur as a result of high river discharges, heavy ice jams, or a combination of the two conditions, the frequency of flooding is somewhat irregular. Discharges in excess of the maximum flow of April 1, 1963, have occurred at least six times during the 25 years of record at Rockland. Nevertheless, none of these periods of high discharge has resulted in a stage as high as the 1963 Ontonagon flood. This emphasizes the influence of ice jams on flooding on the Ontonagon River.

As far as river discharges alone are concerned, the potential for periodic flooding is evident. However, more frequent major flooding occurs as a result of a combination of only moderately high discharges and heavy ice jams.

Duration and Rate of Rise

Flood duration in Ontonagon is dependent primarily on the severity of ice jams near the mouth of the river. There are no recorded gage heights in Ontonagon from which to measure the rise and duration of river stages. However, flood descriptions found in newspaper files have been used to approximate these values for some of the major floods.

A newspaper account of the April 1963 flood states that in an 18-hour period flood waters rose approximately 5 feet. Flood conditions lasted 24 hours until the ice jam finally broke, resulting in a rapid fall of the water level.

An account of the flood of April 1923 tells that in approximately 10 hours the river rose from near bankfull to flood the entire lower portion of the village. The newspaper article further indicates that the flood duration was short. Basically, the flood was composed of a rapid rise in river stage followed by an extremely rapid fall when the ice jam broke.

Velocities

During the April 1963 flood, the velocity was quite low as the flood was caused by large ice jams. In effect, the ice jams acted as a dam, and the flood waters were relatively quiet except at the time of release. Floods caused by high river discharge alone, such as occurred in August 1942, would have been characterized by much higher velocities.

Flooded Areas, Flood Profiles, and Cross Sections

Plates 9 through 11 show the approximate areas along the Ontonagon River in the vicinity of Ontonagon that would be inundated by the Intermediate Regional and Standard Project Floods. The actual confines of these overflow areas on the ground may vary somewhat from those shown on the maps within the limits of the contour interval and scale of the maps used for presentation. Some isolated locations shown within the flood outline may actually be above the flood crest because of elevated foundations and embankments.

Plate 12 shows the high water profile in the vicinity of Ontonagon for the flood of April 1963. Also shown are the profiles for the Intermediate Regional Flood and the Standard Project Flood discussed later in this report.

Plate 13 includes the eight cross sections and two bridge sketches obtained for the Ontonagon River in the reach studied. The locations of all sections are shown on Plates 9 through 11. The elevation and extent of overflow of the Intermediate Regional and Standard Project Floods are indicated on the sections.

FLOOD DESCRIPTIONS

Following are descriptions of known large floods that have occurred on the Ontonagon River in the vicinity of the Village of Ontonagon. These are based on newspaper accounts, historical records, and field investigations.

April 4, 1912

A serious flood occurred in Ontonagon in April 1912 as a result of huge ice windrows which formed along the Lake Superior shoreline. The windrows, which were estimated to be 60 feet high, sealed off the mouth of the Ontonagon River, causing the flooding.

Few details are available regarding the stage and discharge during the 1912 flood. Photographs showing the cause and effect of the flood are presented on Figure 4.

May 1922

Photographs have been obtained which show flood conditions in Ontonagon in May 1922. No other records pertaining to this flood have been discovered. Three of the photographs are included as Figure 5.

April 20, 1923

The flood of April 1923 was caused by spring snow melt and large ice jams at the mouth of the Ontonagon River. A photograph of River Street during this flood is shown on Figure 6.

Figure 4. -- FLOOD SCENES IN ONTONAGON - APRIL 1912

Top view was taken near the mouth of the Ontonagon River where winds from Lake Superior had caused windrows estimated to be 60 feet in height. The windrows sealed off the mouth of the Ontonagon River causing the flood of 1912. Lower view is looking along River Street in Ontonagon during the April 1912 flood.

Figure 5. -- FLOOD SCENES IN ONTONAGON - MAY 1922

These photographs which were taken in the downtown portion of Ontonagon show the severity of the May 1922 flood.

Figure 6. -- FLOOD SCENE IN ONTONAGON - APRIL 1923

This view shows a horse drawn wagon coming down River Street during the 1923 flood.

Below is an excerpt from a newspaper account of the 1923 flood.

THE ONTONAGON HERALD
Saturday, April 28, 1923
<u>LAST FRIDAY'S FLOOD WORST IN MANY YEARS</u>

"The main street from the Board of Trade Cafe to the Citizens State Bank, as well as several whole blocks, was submerged under about eithteen inches of water last Friday afternoon (April 20) when the ice jams at the State bridge and between the piers caused the water in the Ontonagon River to overflow its banks.

"The melting snow in the woods for miles back caused an unusually large amount of water to run to the river, and with the ice at the mouth of the river, it was impossible for the water to escape, the result being that the lower sections of the town were flooded.

"The water began to raise very rapidly early in the morning and by noon it had reached an alarming height. By two o'clock the lower portions of the town were entirely covered with water. At three-thirty the water had reached its height, and had also washed a channel through the ice flows and began to recede. There were at least ten or eleven village blocks entirely under water. The majority of the floors of the stores in the blocks between the Board of Trade Cafe and the Citizens State Bank were flooded to a depth of from half an inch to seven or eight inches.

"On the opposite or lower side of the street, all basements were flooded to a depth of nearly two feet."

"There is no possible way of estimating the damage and property loss, but it will run into many dollars."

August 22, 1942

The largest recorded flood resulting from rainfall occurred in August 1942. High water elevations from this flood rank second only to the April 1963 flood of record. Some photographs taken during the 1942 flood are included as Figure 7.

Figure 7. -- FLOOD SCENES IN ONTONAGON - AUGUST 1942

Upper left view shows damaged U. S. Highway 45 1.5 miles north of Bruce Crossing, Michigan. The stream is the Mile and One-half Creek, a tributary of the Ontonagon River. Upper right view shows flood conditions at the Military Bridge (U. S. Highway 45) over the Ontonagon River two miles south of Rockland, Michigan. Lower view is looking southwest from Stubb's Museum in Ontonagon.

The following is an excerpt from a newspaper account of the 1942 flood at Ontonagon.

THE ONTONAGON HERALD
Saturday, August 29, 1942

WEEKEND FLOOD DAMAGES BRIDGE AT ONTONAGON; VICTORIA BRIDGE OUT

"Not in the memory of the oldest residents of Ontonagon has there been such a rainstorm as that which occurred last Friday evening and Saturday morning. Stories of the damage having been done came to note early Saturday morning.

"The driftwood coming down the Ontonagon River piled up against the abutments at the large cement bridge at the Ontonagon River in Ontonagon, and before noon the matter became serious. The logs, trees, and other debris was so thick that two channels were completely blocked and the tremendous amount of water passing through the west channel undermined the west pier so that the west third of the bridge settled gradually until on Sunday it was down about twenty-four inches.

"Cars were stopped for a time, for fear that the bridge would go out, but after a while a few cars were allowed to pass. After the danger of the bridge drifing away lessened, an approach was made from the settled part of the swing part and traffic was again started."

THREE MEN DROWNED WHEN HOUSE IS CARRIED AWAY
BY FLOOD WATERS LAST FRIDAY

"George Dent, age 79 years, Tommy Mason, age 31 and Joseph Paul Garsanki, age 53, lost their lives in the flood which took place throughout the north end of Ontonagon County last Friday night, August 21.

"The flood waters came down the valley (estimated at 10 to 12 feet deep) and swept the house, which was at the side of the creek, downstream, with all three men asleep. The house, a structure at least 39 x 36 feet with a lean-to 14 x 18 feet, was carried downstream. It struck the Deer Creek Bridge and set the roof of the building on the bridge and cracked the balance of the house, with all funiture, to bits. The bodies of the three men were missing when searching parties went to find them."

April 1, 1963

The worst flood in Ontonagon history occurred in the spring of 1963. The flood resulted from heavy runoff of melting snow combined with thick ice conditions on Lake Superior. Figures 8 through 14 show the severity of the April 1963 flood of record.

The following excerpts from newspaper accounts indicate the magnitude of the 1963 flood.

THE DAILY MINING GAZETTE
Houghton, Michigan
Tuesday, April 2, 1963
ONTONAGON SLOWLY APPROACHING NORMAL AS WATERS RECEDE

"The rampaging Ontonagon River was nearly back to its normal condition during spring thaws this morning as flood waters slipped back into the river bed after ice blocks had been removed.

"A large crane, the property of the Ontonagon-Huss Paper Co., had been employed consistently through the day on Monday removing ice barriers. Along with other volunteer help the water was finally encouraged to move through ice openings, slowly working its way to Lake Superior as the ice chunks also plummented forward on their way out."

"The M-64 highway proceeding southerly and westerly from Ontonagon again was back in use this morning. It was the washed-out stretch near the Huss mill which caused concern. The highway bridge's protective piling had been washed into Lake Superior because of the strong river currents."

Figure 8. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

Top view is an aerial photograph looking south at the flooded Ontonagon River. Note the massive ice jam at State Highway 64 near the center of the photograph. Lower view is looking south-east along River Street in Ontonagon.

Figure 9. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

These photographs show the intensity of the ice jam upstream from State Highway 64 during the April 1963 flood.

Figure 10. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

These photographs show the extent of the 1963 flood at Riverside Marine near the east end of the State Highway 64 Bridge.

Figure 11. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

Upper view shows flood conditions at the residences of Spencer Ross and Keith Roehm on the "island." Lower view was taken from State Highway 64 looking toward the Hoerner Waldorf Paper Mill on the west side of the Ontonagon River.

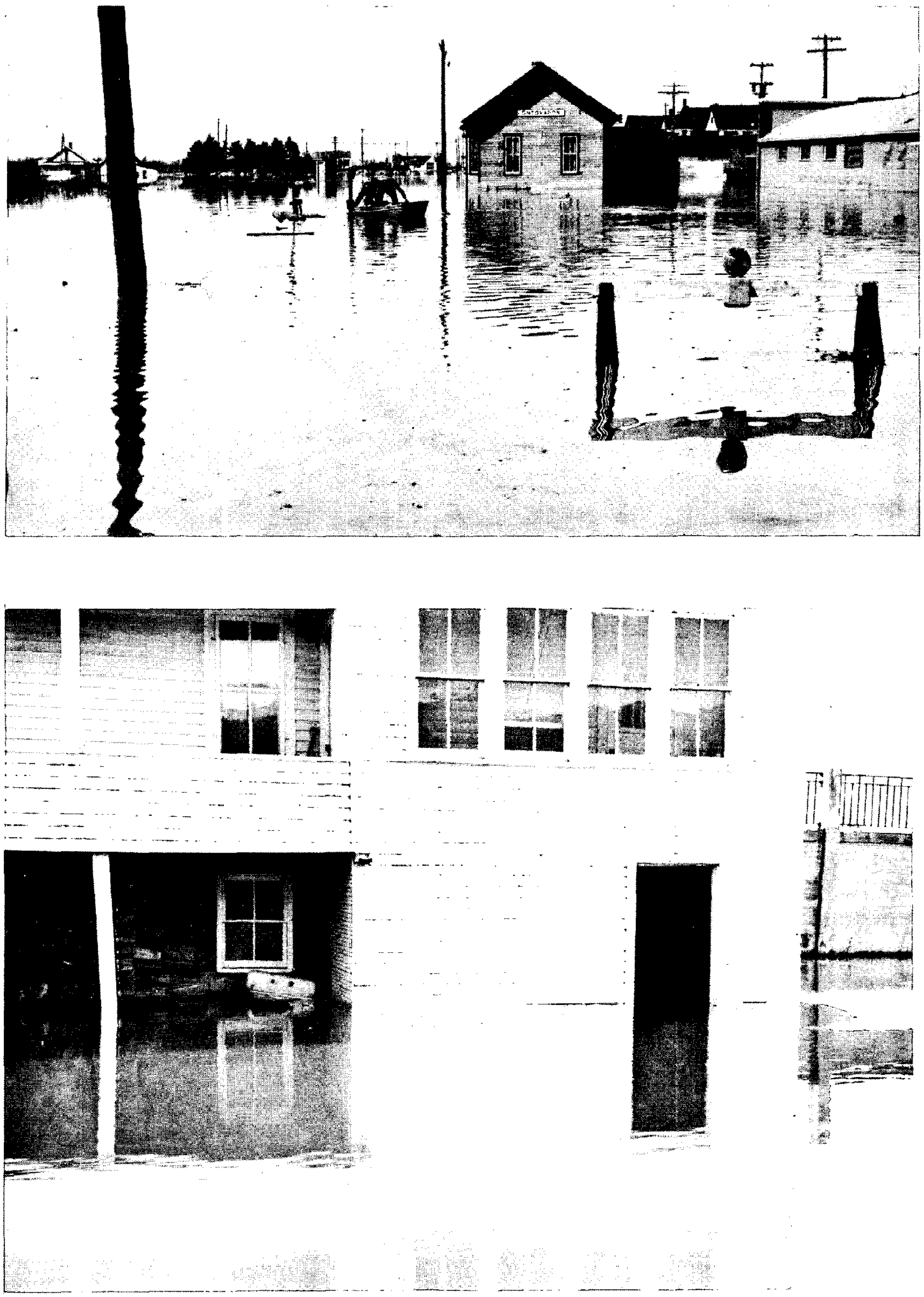


Figure 12. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

Upper view shows flooded conditions around the Ontonagon Railroad Depot. Lower view indicates flooding at a residence in Ontonagon.

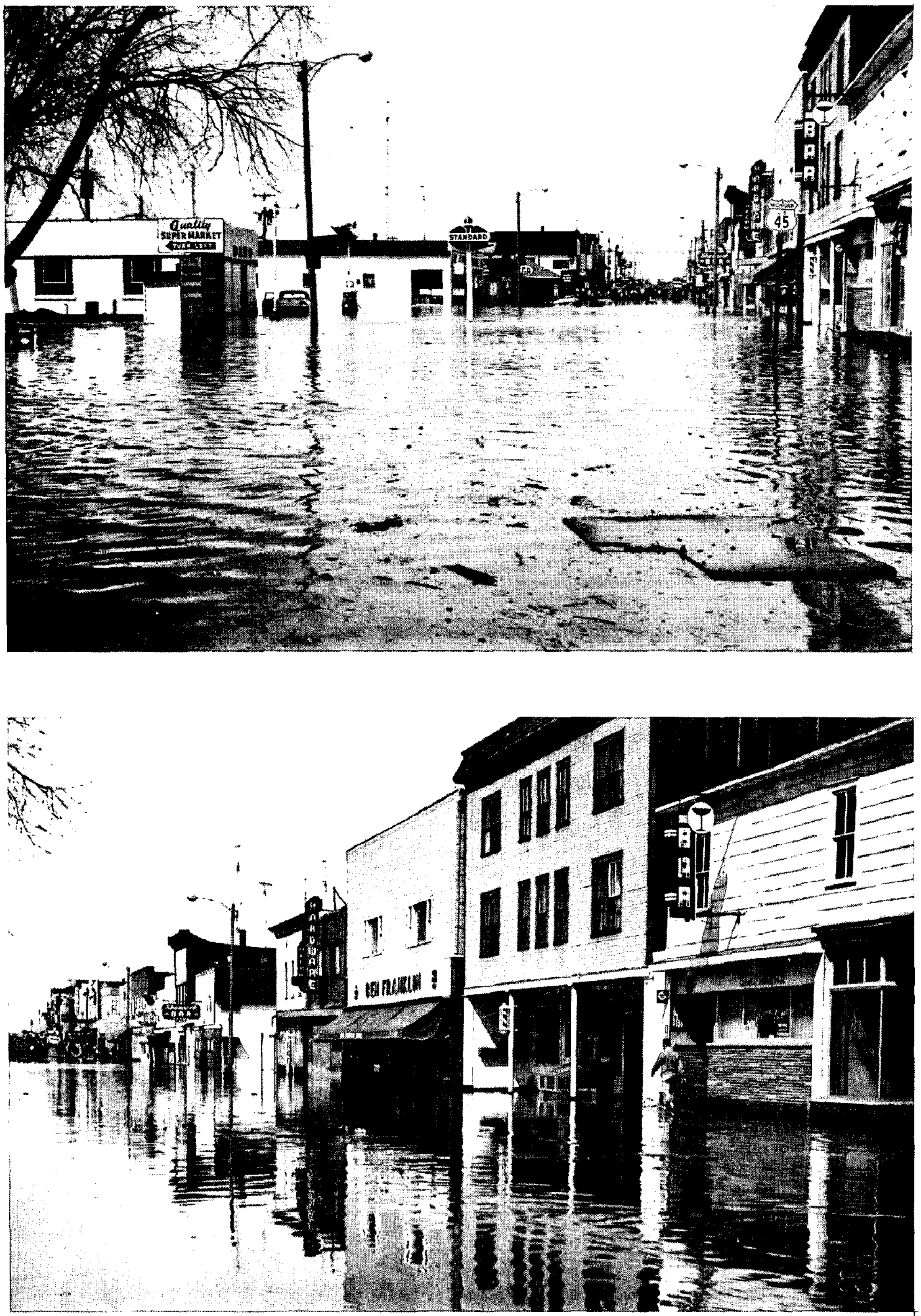


Figure 13. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

These photographs were taken on April 1, 1963, looking northwest along River Street in Ontonagon.

Figure 14. -- FLOOD SCENES IN ONTONAGON - APRIL 1963

Top view is looking northwest along the flooded River Street in Ontonagon. Lower view also shown flooded condition in the commercial area of Ontonagon.

THE ONTONAGON HERALD
Thursday, April 4, 1963

ONTONAGON RIVER FLOODS THE ISLAND SUNDAY NIGHT;
CENTER OF TOWN MONDAY

"The Ontonagon River went on a rampage Sunday night and Monday and caused the worst flood in the village's history. Sunday night icy waters from the river flowed over the entire Island between the Ontonagon River and the slough and by Monday noon the center of the village was completely flooded to a depth of from two to three feet.

"The Village is now attempting to get back to normal after the water receded early Tuesday morning and found its way out into Lake Superior despite the two mile ice jam which still held in the lake. A conservative estimate of the damage has been unofficially placed at a half million or more.

"Some businesses took the precautions when Sunday's unseasonably warm temperatures of 72 degrees caused a heavy runoff of melting snow through the entire area while the thick ice was solid in Lake Superior."

"Monday morning at 11:30 the first heavy flow of ice came down the Ontonagon River and jammed heavily at the railroad bridge. The water then by-passed the bridge on both sides, causing floods in both the east and west sloughs. Water in the west slough crossed M-64 just past the highway bridge putting the road under two feet of water and making a washout four feet wide. This was filled and the road made passable Tuesday morning after the water receded. The River Road and 'Cash farm' were also flooded.

"From the east slough the water swiftly rose, crossed the railroad tracks and quickly flooded the section from Wagar's Apparel to the Gamble Store and back past the County Garage, averaging at least two feet deep. Sunday night and Monday the area of the Hawley Lumber Yards were also flooded to US-45.

"Hard hit also was the 'Penegor Flats' at the end of Trap Street. Swirling water in this area dug huge chunks of the lakeshore bank and endangered the flats from being undermined. These four families were evacuated. Two cars parked there were up to the door handles in water and ice.

"The water line under the railroad bridge, serving the west side of the village was broken during the flood leaving those residents and the Hoerner Boxes, Inc., without water.

"This was the first flood to strike Ontonagon in 40 years. The last one was in the spring of 1923 and the old timers say that although it was a bad one, this one was much worse."

THE ONTONAGON HERALD
Thursday, April 11, 1963
VILLAGE WORKING WAY OUT OF WORST FLOOD

"All floods are caused by obstructions. The water cannot be carried away by the channel and it overflows its banks causing a flood as occurred here last week.

"The Ontonagon River has leaped its banks on several occasions, causing property damage along the main street of the village. All local flooding is the result of ice blocking the river channel proper or the outlet at the mouth. On one occasion in the past a huge iceberg was lodged at the mouth of the river as a result of gale winds forcing the water in big waves that carried the iceberg along with it."

"The April 1, 1963, flood was the most destructive up to this time. There was considerable property damage along the banks of the river. Boat houses were demolished and the watercraft housed within them. Small boats were wrecked by the ice and piled high on adjoining land or washed out into Lake Superior. Nets of commercial fishermen were soaked and caked with mud. They all had to be rewound on reels.

"The current surge of flooding water was the result of rapidly melting snow and unusually high March temperatures. The water damage was very high on the north side of the Ontonagon River where it went over the island, and where it flooded the buildings on the south property of River Street . . . . Also greatly damaged was that area bounded by Copper and Spar Streets going from east to west and from Brass Street and the C.M.St.P.&P. RR Depot north to and across Conglomerate Street."

"Water raised fast when it came; there was no time to move or shift stock in the stores.

"The water varied from three to four feet in depth and soaked the entire area and mercantile stock in its path. As the flood waters receded, a thick coat of red silt and in some places oily substances were deposited over everything the water encompassed.

"Accurate losses may never be determined. One thing is certain, all property in the submerged area suffered tremendous damage and loss. Business was at a standstill. The cleanup processes are slow and are under the direction of the State Pure Food Inspectors. Truckloads of food and other merchandise have been taken to the village dump. Precautions were taken to prevent epidemic of sickness and spread of disease."

FUTURE FLOODS

This section is a discussion of Standard Project Floods, Intermediate Regional Floods, and some of the hazards involved on the Ontonagon River in the vicinity of Ontonagon, Michigan. The Standard Project Flood represents a reasonable upper limit of expected flooding. The Intermediate Regional Flood represents floods that may reasonably be expected to occur more frequently, on the average of once every 100 years. Large floods have been experienced in the past on streams in the general vicinity of Ontonagon. Heavy storms or spring runoff similar to those causing floods on other streams in the region could occur over the Ontonagon River watershed. In this event, floods would result comparable in size with those experienced on neighboring streams. In addition, ice jams which frequently occur on the Ontonagon River during spring runoff could cause even larger floods at Ontonagon. It is, therefore, desirable in connection with any determination of future floods which may occur on the Ontonagon River to consider storms and floods that have occurred in the region on watersheds with similar topography, watershed cover, and physical characteristics.

DETERMINATION OF INTERMEDIATE REGIONAL FLOODS

The Intermediate Regional Flood is defined as having an average frequency of occurrence in the order of once in 100 years at a designated location. The flood may occur in any year. Some probability estimates are based on statistical analyses of stream flow records for the watershed under study, but limitations in such records require analyses of rainfall and runoff characteristics in the "general region" of the area of study. The Intermediate Regional Flood represents a major flood, although it is much less severe than the Standard Project Flood.

The Intermediate Regional Flood for the Ontonagon River in the vicinity of Ontonagon is based on a statistical analysis of the 25 years of records obtained at the U. S. Geological Survey gage near Rockland, Michigan. Transposition of this data to Ontonagon was made with consideration of the drainage area difference between the two locations. Also considered were past flood stages at Ontonagon and the effect of ice jams and Lake Superior levels. Table 5 lists the maximum known floods that have occurred on watersheds which are comparable with the Ontonagon River, and are within the same geographical region.

The Intermediate Regional Flood represents a peak discharge of 38,000 cfs on the Ontonagon River at Ontonagon. This flood could be caused by snowmelt, heavy rains, or a combination of the two. Intermediate Regional Floods on the Ontonagon River in the reach investigated would be approximately 0.5 feet higher than the April 1963 flood of record within the village limits of Ontonagon.

DETERMINATION OF STANDARD PROJECT FLOODS

Only in rare instances has a specific stream experienced the largest flood that is likely to occur. Severe as the maximum known flood has been on any given stream, it is a commonly accepted fact that in practically all cases a larger flood can and probably will occur at some time in the future. A Standard Project Flood for the Ontonagon River at Ontonagon has been estimated at a level 1.0 feet above the Intermediate Regional Flood crest. This method of estimating the Standard Project Flood stage appears to be more practicable than attempting to calculate a flood level from a theoretical discharge because of ice jams which frequently occur near the mouth of the Ontonagon River. Also, sufficient data was not available to establish an open water rating curve at Ontonagon.

TABLE 5

MAXIMUM KNOWN FLOOD DISCHARGES ON STREAMS IN THE REGION OF ONTONAGON, MICHIGAN

Stream	Location	Drainage Area Sq. Mi.	Date	Peak Discharge Amount cfs	Peak Discharge Per Sq. Mi. cfs
Flambeau River	Near Bruce, Wisc.	1,897	May 1, 1954	17,400	9.2
Menominee River	Near Florence, Wisc.	1,780	Apr. 26, 1960	19,500	11
Chippewa River	Near Bruce, Wisc.	1,630	Sept. 1, 1941	25,800	16
Ontonagon River	Near Rockland, Mich.	1,340	Aug. 22, 1942	42,000	31
Flambeau River	At Babbs Island near Winter, Wisc.	1,000	June 25, 1946	9,440	9.4
Wisconsin River	At Rainbow Lake near Tomahawk, Wisc.	750	Sept. 5, 1941	3,570	4.8
Sturgeon River	Near Arnheim, Mich.	705	Apr. 20, 1952	15,500	22
Bad River	Near Odanah, Wisc.	611	Apr. 24, 1960	27,700	45
South Branch Ontonagon River	At Ewen, Mich.	348	Apr. 24, 1960	13,500	39
Sturgeon River	Near Alston, Mich.	346	Apr. 24, 1960	7,360	21
East Branch Ontonagon River	Near Mass, Mich.	272	July 1, 1953	4,590	17
White River	Near Ashland, Wisc.	269	July 1, 1953	6,270	23
Montreal River	Near Saxon, Wisc.	262	Apr. 24, 1960	6,600	25
Presque Isle River	Near Tula, Mich.	261	Apr. 25, 1960	4,640	18
Middle Branch Ontonagon River	Near Trout Creek, Mich.	203	Nov. 7, 1951	1,750	8.6
Black River	Near Bessemer, Mich.	200	Apr. 24, 1960	14,800	74
Presque Isle River	At Marenisco, Mich.	171	Apr. 25, 1960	3,520	21
Sturgeon River	Near Sidnaw, Mich.	171	Apr. 24, 1960	4,630	27
Middle Branch Ontonagon River	Near Paulding, Mich.	164	Apr. 30, 1951	2,050	13
West Branch Ontonagon River	Near Bergland, Mich.	162	Apr. 26, 1960	1,400	8.6
Otter River	Near Elo, Mich.	162	Apr. 19, 1952	4,540	28
Iron River	At Caspian, Mich.	92.1	July 2, 1953	1,430	16
Cisco Branch Ontonagon River	At Cisco Lake Outlet, Mich.	50.7	May 1-4, 1951	288	5.7

Frequency

It is not practicable to assign a frequency to the Standard Project Flood. The occurrence of such a flood would be a rare event; however, it could occur in any year.

Possible Larger Floods

Floods larger than the Standard Project Flood are possible; however, the combination of factors that would be necessary to produce such floods rarely occur. The consideration of floods of this magnitude is of greater importance in some problems than in others, but should not be overlooked in the study of any problem.

HAZARDS OF GREAT FLOODS

The amount and extent of damage caused by any flood depends, in general, upon the extent of area flooded, height of flooding, velocity of flow, rate of rise, and duration of flooding.

Areas Flooded and Heights of Flooding

The areas along the Ontonagon River flooded by the Standard Project Flood and the Intermediate Regional Flood are shown on Plates 9 through 11. An index for these maps is presented on Plate 8. Depth of flow at a particluar point can be estimated from the crest profiles which are shown on Plate 12.

The Intermediate Regional Flood profile for the Ontonagon River was computed using stream characteristics for selected regions as determined from observed flood profiles, topographic maps, and valley cross sections from a recent survey by the Corps of Engineers. Clogging of the bridges and harbor by ice jams has also been considered. Plate 13 presents the eight cross sections and two bridge sketches used in this study. The Standard Project Flood profile is estimated to be 1.0 foot higher than the Intermediate Regional Flood. The elevation of both these floods is shown on the cross sections of Plate 11. The elevations shown on Plates 12 and 13 and the overflow areas shown on Plates 9 through 11 have been determined with an accuracy consistent with the purposes of the study and the accuracy of the basic data.

The Intermediate Regional Flood profile for the Ontonagon River averages 0.5 feet higher than the April 1963 flood. The Standard Project Flood would be 1.5 feet higher than the 1963 flood.

Figures 15 through 26 on the following pages show the heights that would be reached by the Standard Project and Intermediate Regional Floods on facilities presently existing within the flood plain in the vicinity of Ontonagon. Elevations of the flood of record are also shown.

Velocities, Rate of Rise, and Duration

Water velocities during floods caused by high discharge depend largely upon the size and shape of the cross section, the condition of the stream, and the bed slope, all of which vary on different streams and at different locations on the same streams. During floods which result from ice jams the velocity would not be significant except at the time of release.

Duration and rate of rise are difficult to predict for rivers subject to ice jams. At Ontonagon, the rate of rise would be rapid once the river outlet became plugged. The duration of the Intermediate Regional and Standard Project Floods would be dependent on the severity of the ice jam and the effectiveness of ice clearing techniques.

Figure 15. -- FLOOD HEIGHTS AT HOERNER WALDORF PAPER MILL

During the April 1963 flood the Hoerner Waldorf Mill was forced to shut down because of damage caused by flood waters on the Ontonagon River. Higher levels may be expected during the Standard Project and Intermediate Regional Floods as shown on the photographs.

Figure 16. -- FLOOD HEIGHTS AT NEW MARINA

High water levels which may be expected during the Standard Project and Intermediate Regional Floods at the new marina which is under construction along the west bank of the Ontonagon River are shown above.

Figure 17. -- FLOOD HEIGHTS ALONG EAST SIDE SLOUGH

This residential area located near the east side slough was flooded to the depth shown on the photograph in April 1963. Future floods are expected to go even higher as shown by the Standard Project Flood and Intermediate Regional Flood arrows.

Figure 18. -- FLOOD HEIGHTS AT ONTONAGON COUNTY ROAD COMMISSION GARAGE

Flood waters covered the floor of this building located along Trap Street during the April 1963 flood. Levels which may be expected during the Intermediate Regional Flood and Standard Project Flood are shown on the staff gage.

Figure 19. -- FLOOD HEIGHTS AT CITIZENS STATE BANK

Projected future flood levels and the level experienced during the 1963 flood are shown on this photograph which was taken at the corner of River and Spar Streets in Ontonagon.

Figure 20. -- FLOOD HEIGHTS AT IGA FOODLINER

Merchandise in the store was extensively damaged when flood waters reached the level shown by the 1963 arrow. Even greater flooding would occur during an Intermediate Regional or Standard Project Flood.

Figure 21. -- FLOOD HEIGHTS AT EAGLES CLUB

Past and projected future flood heights are shown at this location near the intersection of Quartz and Michigan Streets in Ontonagon.

Figure 22. -- FLOOD HEIGHTS AT QUALITY SUPER MARKET

In April 1963 food stock within this store was damaged extensively. The level reached by the 1963 flood and levels which may be expected during an Intermediate Regional Flood and a Standard Project Flood are shown on the staff gage photograph.

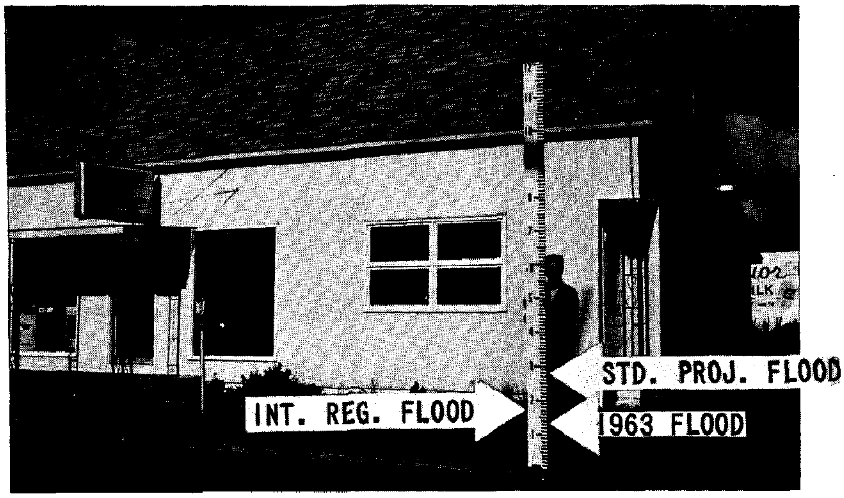


Figure 23. -- FLOOD HEIGHTS AT SEARS CATALOG SALES

This store located at the corner of Copper and Michigan Streets in Ontonagon may expect flood waters to be 1.8 feet and 2.8 feet deep during the Intermediate Regional and Standard Project Floods. The crest of the 1963 flood was slightly over 1 foot deep at this location.

Figure 24. -- FLOOD HEIGHTS AT THE FIRE HALL

Flooding which extended for several blocks on River Street in 1963 was also evident at this location at the Ontonagon Village Fire Hall. Even greater depths, 2.0 feet for the Intermediate Regional Flood and 3.0 feet for the Standard Project Flood, may be anticipated.

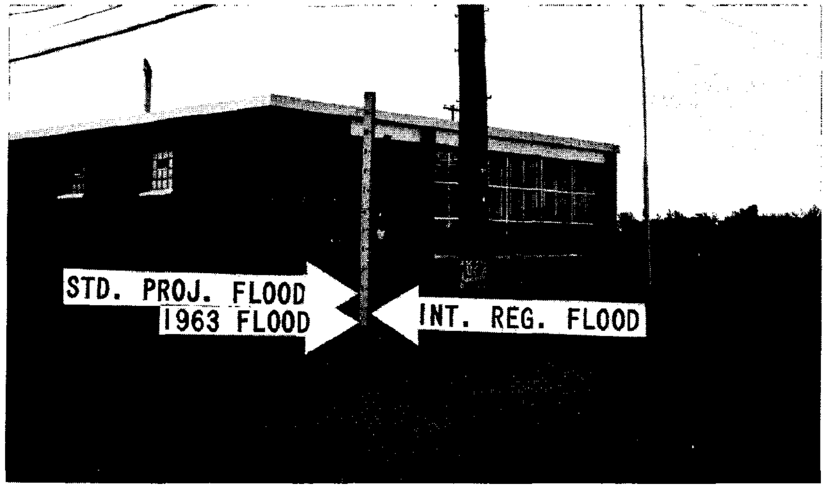


Figure 25. -- FLOOD HEIGHTS AT U. S. POST OFFICE

Although this building was not damaged by the 1963 foood it is vulnerable to the design floods of the future as shown on this photograph.

Figure 26. -- FLOOD HEIGHTS AT HAWLEY LUMBER YARD

This building located on Iron Street in Ontonagon was subject to the 1963 flood and may expect even higher levels during the Intermediate Regional and Standard Project Floods. The projected flood crests are shown above.

PAST SHORE EROSION

LAKE SUPERIOR

Erosion Damage Prevention Measures

In response to a resolution of the Committee on Public Works of the House of Representatives dated March 26, 1952, a preliminary examination report was made, which, among other things, determined the extent of shore property damages from the high water levels on the Great Lakes during the one year period from May 1951 through April 1952. The report stated that from 15 miles west to about 5 miles east of Ontonagon, erosion caused losses of up to 50 feet in depth from lake front lots. In addition, many of the nearly 100 homes and cabins in this reach of shoreline were destroyed or had to be moved. The report further stated that cribbing and riprap that had been used to protect a few of the improved properties were too light in construction to be effective. To this date, essentially all erosion prevention measures have been small scale efforts by individual property owners.

The role of the Federal Government in erosion damage prevention is one of making studies of the problem areas and then participating in the cost of approved erosion prevention measures. A complete description of the applicable Federal Government programs is presented subsequently in this report.

Several local property owners along the Lake Superior shoreline in Ontonagon County have banned together to form the "Ontonagon County Lake Shore Erosion Association." This group has been active in seeking more rigid control of lake levels as a means of reducing erosion damage.

Erosion Forecasting Services

There is no official erosion forecasting service for the area.

The Lake and Its Shoreline

Lake Superior, the largest of the Great Lakes, has a water surface area of 31,700 square miles and a drainage area of 80,100 square miles. The United States portion of Lake Superior consists of 20,600 square miles of water surface and 37,500 square miles of drainage area. Of the 1,622 miles of shoreline in the United States, there are 1,041 miles in Michigan, 367 miles in Wisconsin, and 214 miles in Minnesota.

The shoreline studied in this report comprises two sections of the Ontonagon County, Michigan, lake frontage which have been subject to shoreline erosion. The "West Coast" study area, as shown on Plate 2, extends from the most northerly point of the Porcupine Mountains (about 1.5 miles west of Union Bay) easterly nearly 25 miles to a point 3,000 feet northeast of the mouth of the Firesteel River. Also shown on Plate 2 is the "East Coast" study area which covers about three miles of beach northeasterly from the Misery River to the Houghton County line. Other sections of beach in Ontonagon County outside the two study reaches have not been subject to significant erosion.

Numerous streams enter Lake Superior from Ontonagon County, providing this portion of the lake with a large sediment inflow. The locations of the streams are shown on Plate 2.

The only major village in the coastal area is Ontonagon, having a population of about 2,500. Smaller communities include Silver City and Green, 13 miles and 6.5 miles west of Ontonagon, respectively. As shown in Table 6, approximately 41,600 linear feet (7.8 miles) of the 28-mile study area is in public ownership. Therefore, approximately 72 percent of the shoreline is privately owned.

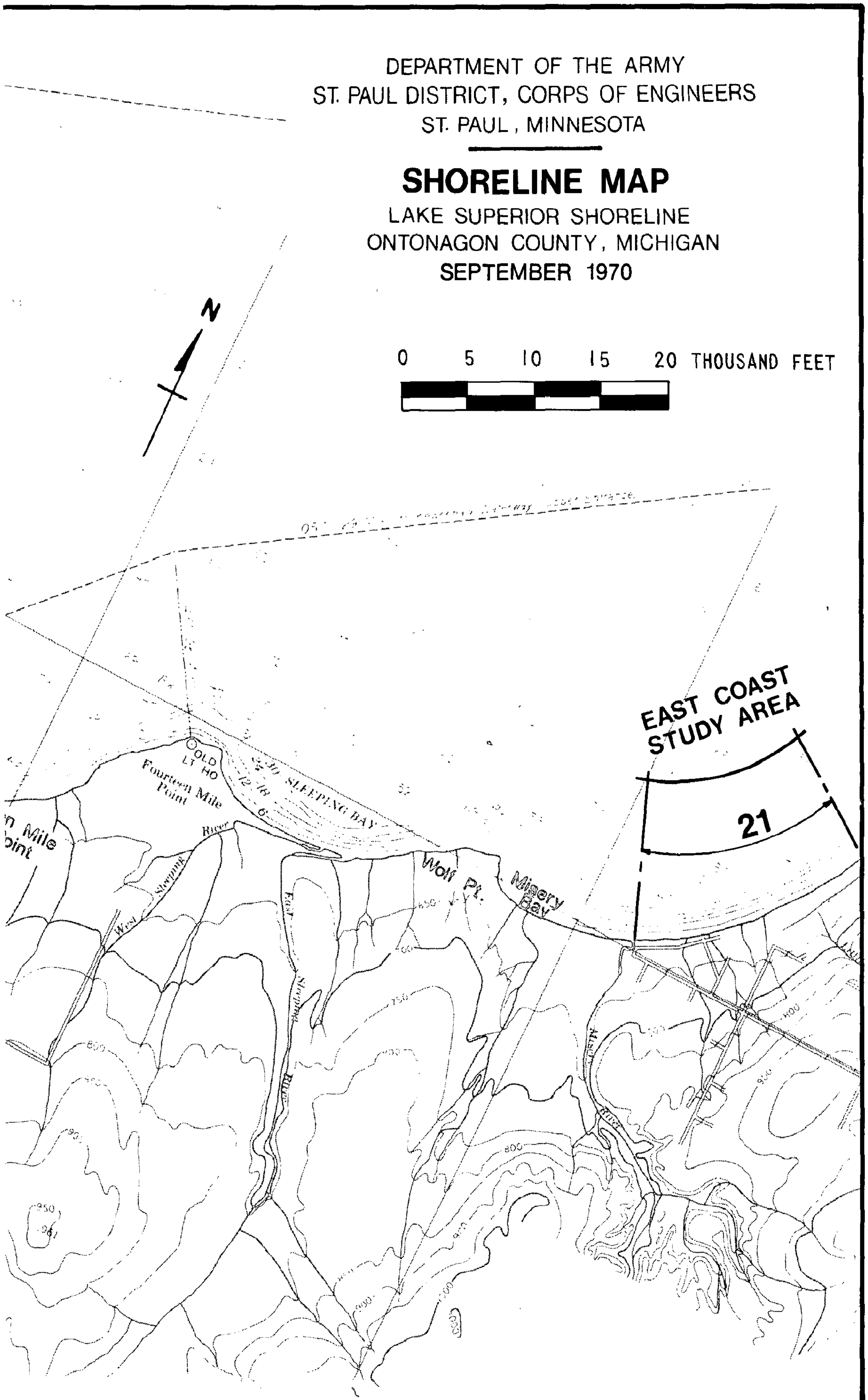

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
SHORELINE MAP
LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970
N
0 5 10 15 20 THOUSAND FEET
EAST COAST STUDY AREA
21
OLD LT HO
Fourteen Mile Point
SLEEPING BAY
Wolf Pt.
Misery Bay
West Sleeping River
East Sleeping River
Misery River

PLATE 2

TABLE 6

PUBLIC OWNED LAKE SUPERIOR SHORELINE

Ownership	Location	Approximate Frontage lin. ft.
State of Michigan	Porcupine Mountains State Park	30,000
State Highway Dept.	Union Bay	7,600
Silver City	Community Park	300
Ontonagon	Township Park	1,600
Ontonagon County	Park at Firesteel River	2,100
Total within study reach		41,600

The resistance of the coast materials to all forms of erosive action varies from stable at rock outcrops to vulnerable at clay cliffs. The general plan of the coastline shows a pattern of rocky headlands and receding beaches. Occasionally, sufficient beach material is transported and deposited in front of the receding areas to form an effective barrier against further erosion. The effectiveness of the beach becomes greatly reduced however, when lake levels rise.

Beach Description

For convenience of identification, the two coastal strips comprising the west and east coast study areas have been subdivided into reaches as shown on Plate 2. These may be described as follows:

Reach No. 1. This reach begins at the westerly end of the study area and comprises the first 11,000 feet of shoreline. Along this reach, the shoreline follows a wave cut cliff in erosion resistant red sandstone with no sand beach. A typical view of Reach No. 1 is shown on Figure 27.

Figure 27. -- TYPICAL SHORELINE - REACH NO. 1

Reach No. 2. State Highway 107 parallels the shoreline in the vicinity of Union Bay and is threatened by erosion. At one section in the middle of this reach, the recession of 1968 necessitated placement of about 1,000 feet of random stone seawall protection as shown on Figure 28. Similar protection has been required at several locations east of the Union River.

Along Reach No. 2, the beach width ranges from 15 to 50 feet. The wave cut scarp for the first 3,000 feet of Union Bay is comprised of a red clay that is very hard when dry, but plastic when wet. A typical cross section of this reach is presented on Figure 29.

East of Union River the bank has cut back to within 10 feet of the highway at several locations and stone fill has been placed at several locations.

Figure 28. -- HIGHWAY PROTECTION - REACH NO. 2

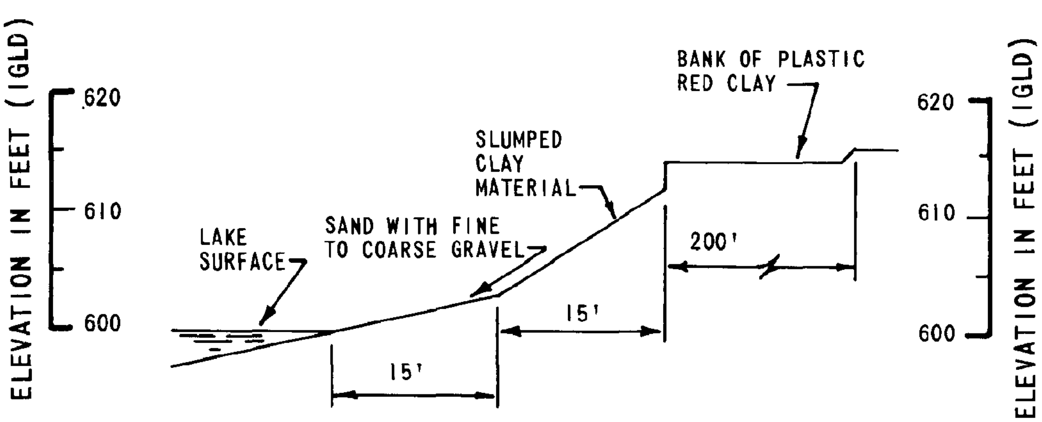


Figure 29. -- TYPICAL BEACH CROSS SECTION - REACH NO. 2

Reach No. 3. East of Union Bay State Highway 107 leaves the shoreline and the sandy beach ends. Figure 30 shows the heavy cobblestone beach which is typical of Reach No. 3. Rocky outcrops have prevented recession for this 3,000-foot reach except for two small embayments.

Figure 30. -- TYPICAL SHORELINE - REACH NO. 3

Reach No. 4. This reach extends from the rocky point on the east bank of the Little Iron River to another rocky point 1,800 feet east. Shoreline recession is active here. Several houses are threatened; at least two may be destroyed in the near future. The extent of erosion is depicted by the accompanying photograph (Figure 31) which was taken along Reach No. 4.

Figure 31. -- PROPERTY DAMAGE - REACH NO. 4

Reach No. 5. The distance between the end of Reach No. 4 and Silver City at the mouth of the Big Iron River is about 3,000 feet. Big Iron River discharges into the lake between two rocky points that act as natural jetties, but which fail to impound littoral material. All along Reach No. 5, the upland is of low relief, being only about five feet above lake level. One house, located about 500 feet to the west of the Big Iron River, has been protected by a timber mat and concrete seawall located only 12 feet lakeward of the house (see Figure 32). The top of the concrete is about 4.5 feet above the present lake level which allows waves and spray to overtop it during storms. West of this protection the shore has receded to the back of the house.

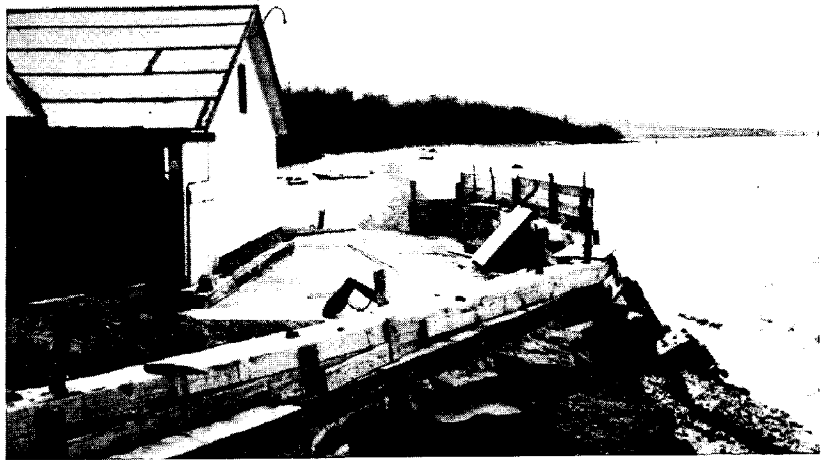


Figure 32. -- EFFECTIVE SEAWALL INSTALLATION - REACH NO. 5

Reach No. 6. Gull Point, which lies 5,200 feet east of the Big Iron River, represents the east end of Reach No. 6. The westerly half of this reach has a narrow, steep beach terminating on the east with a slight erosion resistant point. This portion of the shoreline is straight and subject to only limited recession because of the heavy red sandstone shingle and gravel beach. A typical section is shown below as Figure 33.

Active erosion is evident in the westerly half of the reach to Gull Point with not more than 10 feet of steep beach between the lake and the tree line. Gull Point is rocky with a lakeward extension in the form of a small rocky island. It is generally non-erodible and fixes the shoreline at this position.

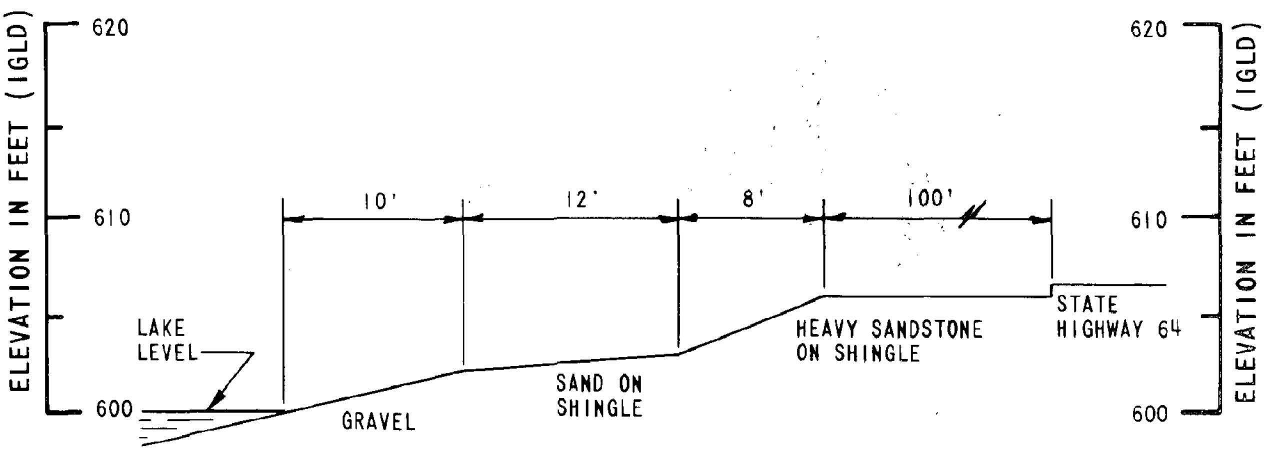


Figure 33. -- TYPICAL BEACH CROSS SECTION - REACH NO. 6

Reach No. 7. This reach extends from Gull Point to a sharp rocky sandstone point about 3,000 feet east. Between these stable points the embayment has reached a depth of 600 to 700 feet. The beach, which is fed by sand size materials deposited by Mineral River, has a substantial width of 75 feet or more, but the upland is of low relief as shown in the following photograph (Figure 34). The beach berm has been overtopped during storms and sand has occasionally washed back as far as State Highway 64.

Figure 34. -- TYPICAL SHORELINE - REACH NO. 7

Reach No. 8. To the east a second embayment extends another 2,000 feet and terminates in a broad headland of non-erodible material (see Figure 35). Erosion and shore recession is active between these points leaving only a narrow, steep beach between the lake and the tree line. This embayment is about 600 feet deep from a line drawn between the adjacent headlands.

Reach No. 9. The next 10,000 feet extending almost to the mouth of Stony Creek is armored with a heavy red sandstone shingle which provides a resistant shoreline. A small embayment in the middle of this reach is completely armored. Here the beach is steep and narrow but is all of heavy sandstone shingle. The red sandstone along Reach No. 9 is stratified, fractured, semi-blocky, and dipping lakeward. It appears that these sandstone formations break down into heavy shingle by freezing and thawing activity.

Figure 35. -- EROSION RESISTANT SHORELINE - REACH NO. 9

Reach No. 10. The next 2,600 feet of beach centering on Pine Creek is steep and sandy with only about 15 feet wide between the lake and the tree line. Figure 36 is a photograph of a typical portion of Reach No. 10. Pine Creek appears to be a heavy contributor of sand and a delta 100 feet wide has formed at its mouth. Houses at the east end of this embayment are generally located a sufficient distance from the eroding beach and only one appears to be in danger. The beach cross section is similar to that of Reach No. 6 as shown on Figure 33. The eastern 1,000 feet of Reach No. 10 consists of a rocky headland and erosion resistant rocky beach. This is the last such headland for a considerable distance along the coast.

Figure 36. -- TYPICAL SHORELINE - REACH NO. 10

Reach No. 11. Reach No. 11 consists of 11,000 feet of shoreline terminating on the east at Green. The beach is fairly uniform with shore material which is readily erodible. Midway of Reach No. 11, sandstone appears at the surface near the waters edge. This sandstone may assist in preventing recession during periods of low lake levels but would be insufficient to be effective during high lake levels. A beach section typical of this area is shown on Figure 37.

In 1935, a 250-foot length of vertical concrete seawall was constructed about 2,000 feet west of Green. The 10-foot beach originally in front of this seawall was lost, allowing undermining of the structure which collapsed. Recession has now reached 50 feet shoreward of its remains. The unprotected flanks have eroded more intensely and the shoreline has recessed an additional 40 feet to the east.

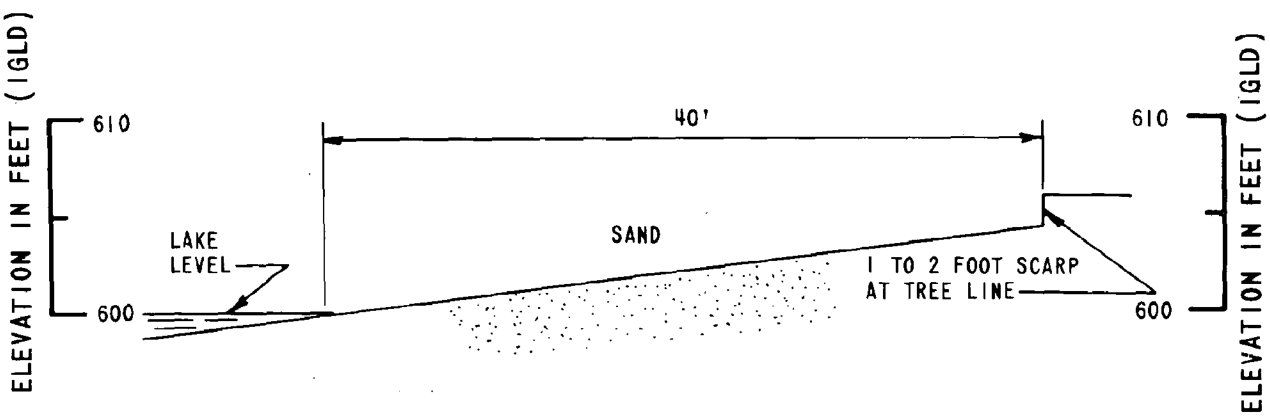


Figure 37. -- TYPICAL BEACH CROSS SECTION - REACH NO. 11

Further to the west, other localized efforts have been made to prevent building losses and shoreline recession by various types of short seawalls ranging from 100 to 150 feet in length. One typical installation is shown on Figure 38. The seawalls are of various designs including stone filled timber cribs fronted by short groins, stone filled timber cribs with concrete caps, and triangular concrete blocks laid end to end. Substantial maintenance is required as the walls are often overtopped by storm waves. The protection provided by the seawalls is marginal as the shoreline continues to recede on each side of the structures. Additional extensions shoreward at the ends of these walls will become necessary as erosion continues.

Figure 38. -- MARGINAL SEAWALL INSTALLATION - REACH NO. 11

A municipal park in the community of Green has a good beach with a general appearance of stability, although eroding areas have developed at both ends. Stability appears to be reinforced by material brought to the beach by rivers on each side, the park being possibly at a nodal point. Little evidence of serious erosion exists for a distance of 1,000 feet centering on the park. Gravel was noted along the plunge point zone.

Reach No. 12. For the 4,000-foot reach eastward from Green to the mouth of the Cranberry River, the beach is fairly wide except for the last 600 feet where it narrows down and several buildings are threatened. Recession was particularly active here during the 1968 period of high lake levels.

The Cranberry River is a sediment contributor and a westward trailing spit has developed at its mouth. This spit indicates that at this particular location the net littoral transport is from east to west nourishing Reach No. 12.

Reach No. 13. From the Cranberry River eastward to the Potato River, a distance of about 9,000 feet, the beach ranges from 80 feet in width immediately east of the Cranberry River to 30 feet in width at the Floodwood River. Basically, the beach steepens as it becomes narrower. A new house was noted under construction near the Floodwood River. This building is located about 30 feet from the top of the beach berm. A typical cross section of this reach of beach is given below on Figure 39. The general appearance of this area is shown in the photograph on the following page (Figure 40).

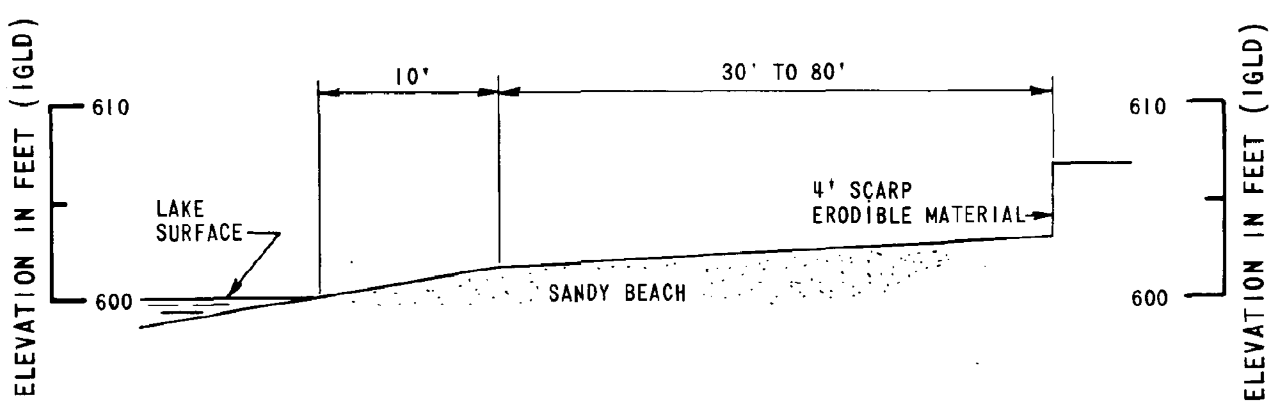


Figure 39. -- TYPICAL BEACH CROSS SECTION - REACH NO. 13

Figure 40. -- TYPICAL SHORELINE - REACH NO. 13

On the west bank of the Potato River a house constructed on the edge of the scarp is protected by rock filled timber crib and old truck tires filled to break up wave action. A photograph of these efforts is included as Figure 41. Similar to the Cranberry River, the Potato River trails to the west denoting a localized long-term net westerly littoral transport.

Reach No. 14. From the Potato River to Dreiss Creek, a distance of 5,200 feet, the beach forms a series of shallow scallops having lakeward points consisting of deposits of 3- to 4-inch cobbles (see Figure 42). Otherwise, the beach is uniform, 40 to 45 feet wide, ending in a 2- to 4-foot scarp in friable materials with active recession of the shoreline. Dreiss Creek does not appear to carry much sediment.

Figure 41. -- TYPICAL SHORELINE PROTECTION - REACH NO. 13

Figure 42. -- TYPICAL SHORELINE - REACH NO. 14

Reach No. 15. This reach includes the 12,000 feet of shoreline from Dreiss Creek to the west jetty at Ontonagon Harbor. For the west half of Reach No. 15, the beach is approximately 70 feet wide as shown on Figure 43 below. Ground elevation is about 8 feet above lake level. At about the midpoint of Reach No. 15, a dragline is used to move sand and gravel from the beach to a stockpile for construction use. A slight scallop is apparent at this point. East of the dragline the beach widens to about 90 feet for the first 3,000 feet and then narrows to not more than 40 feet for the remaining distance to the accretion fillet caused by the west jetty. At locations where the beach is narrow, about 100 feet of dune sand and dune grass lie between the top of the beach berm and the tree line. It is believed that this is the remains of an old relic dune presently being eroded.

Figure 43. -- TYPICAL SHORELINE - REACH NO. 15

The fillet on the west side on the Ontonagon River mouth starts to widen about 2,000 feet west of the harbor and is 300 feet wide at the west jetty. On the east jetty, the sand fillet does not extend as far lakeward; a difference of 400 feet exists between the west and east sides of the harbor. Stabilization of the shoreline in this position appears to be due to the angle the jetties make with the shore combined with the direction of wave approach which creates a greater sheltered area on the west side. Also, land fill has been placed near the west jetty by the adjacent paper mill. During periods of easterly drift, sand builds up against the west jetty and becomes trapped there during periods of westerly drift. The reverse is true on the east side of the harbor.

Within the study area more sediment-carrying streams enter the lake to the west of the harbor than to the east. This is another reason for the greater extent of the west fillet.

Reach No. 16. This reach includes the shoreline from the Ontonagon River to the west end of Township Park, a distance of about 6,000 feet. The beach fillet and wide beach extend eastward for about 2,000 feet from the Ontonagon Harbor. Figure 44 shows a cross section representative of this area. Further east the beach is typified by a narrow, steep section only 20 feet wide fronting a 2-foot scarp, as shown on Figure 45. The shore is about 6 feet above lake level and is of erodible material. Lake Shore Road lies 120 feet back from the top of the scarp but erosion is active. This condition continues for about 4,000 feet to Township Park.

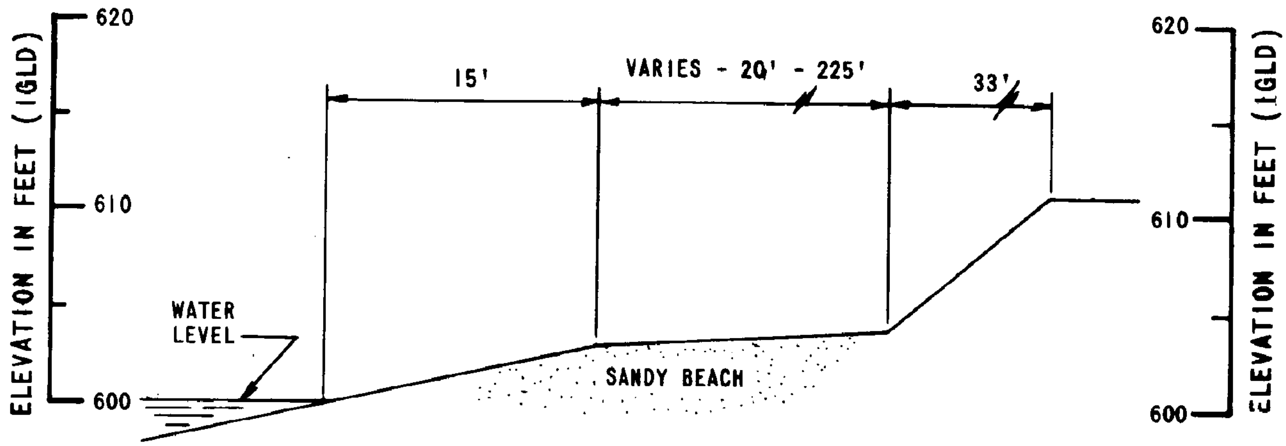


Figure 44. -- TYPICAL BEACH CROSS SECTION - WESTERN REACH NO. 16

Figure 45. -- NARROW SHORELINE - EASTERN REACH NO. 16

The remains of an old pier lie 1,000 feet west of Township Park. Between this pier and the park, a house has been protected by a short seawall constructed of broken concrete, brick, stone, and concrete filled tires with two short 10-foot groins constructed of old tires and piles (see Figure 46). The shoreline has receded 15 feet on the west side and 20 feet on the east side of the seawall. While the seawall is holding fairly well, extensions will be required along the sides in addition to periodic maintenance.

Figure 46. -- LOCAL SHORELINE PROTECTION - EASTERN REACH NO. 16

Reach No. 17. Reach No. 17 extends from the west end of Township Park to Paddys Creek, a distance of 4,500 feet. Recession of at least 50 feet at the park buildings is indicated by the remains of an old concrete structure. This section of the coast is comprised of a highly erodible material. Near the east end of the park, the erodible material changes to a more erosion resistant, highly laminated shale which continues for 600 feet. Between this shale area and Paddys Creek the material is erodible and recession has been active even though the banks are higher.

Reach No. 18. The reach between Paddys Creek and Bear Creek is about 12,000 feet. Shale is exposed to the east of Paddys Creek and has caused a point to form about 300 feet from the creek. A 50-foot wide beach with scattered boulders is continuous from the end of the shale for the next 5,000 feet to the east. A typical profile is shown on Figure 47.

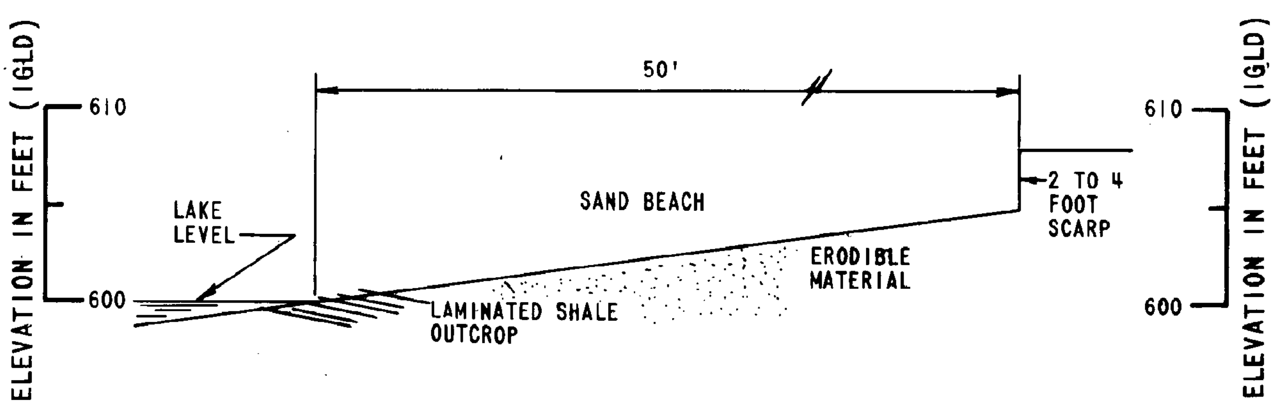


Figure 47. -- TYPICAL BEACH CROSS SECTION - WESTERN REACH NO. 18

The last 7,000 feet easterly to Bear Creek has steep, narrow beaches showing active shoreline recession and outcropping of non-resistant laminated shale formations (see Figure 48). In some of the shale areas, recession is essentially dormant.

Reach No. 19. The 13,000-foot shoreline from Bear Creek to the Flintsteel River is designated as Reach No. 19. The beach here is uniformly wide as shown on Figure 49 and offers no erosion problem during present lower lake levels. Net littoral movement in this area is from west to east as evidenced by Bear Creek which trails to the east.

Figure 48. -- TYPICAL SHORELINE - EASTERN REACH NO. 18

Figure 49. -- TYPICAL SHORELINE - REACH NO. 19

Reach No. 20. From the Flintsteel River to the east end of the "West Coast" study area is about 7,000 feet. The beach through the west part of this reach averages about 50 feet in width fronting a 4- to 5-foot scarp of easily erodible material (see Figure 50). Farther east the beach narrows and steepens to a width of about 35 feet with a 1- to 2-foot scarp. A typical section in this reach is sketched as Figure 51.

The Firesteel River enters Lake Superior about 4,200 feet east of the Flintsteel River. Both rivers appear to be substantial sediment contributors. A delta has formed at the mouth of the Flintsteel River with a slight trend to the west; however, no specific direction of littoral drift predominates.

Figure 50. -- TYPICAL SHORELINE - WESTERN REACH NO. 20

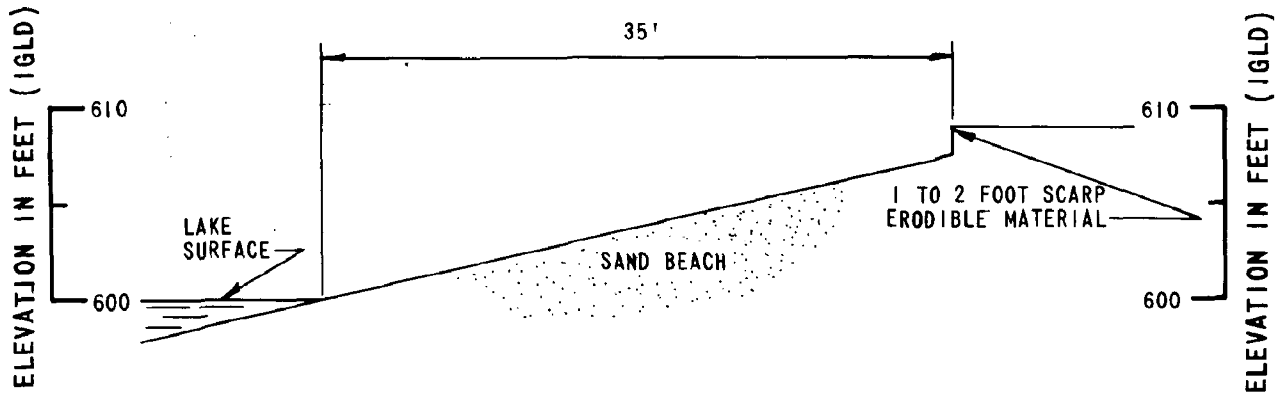


Figure 51. -- TYPICAL BEACH CROSS SECTION - EASTERN REACH NO. 20

Reach No. 21. The last reach of shoreline included in this study is that extending easterly from the mouth of Misery River for a distance of about 18,000 feet to the Houghton County line. Besides Misery River, several small creeks and the Little Elm River enter the lake in this reach. Only Misery River appears to be a substantial source of littoral material.

For the first 2,000 feet east of Misery River the beaches are up to 125 feet wide fronting a low water berm and a 2-foot scarp. The elevation of the coast is 10 to 12 feet above lake level. Evidence of sand dune formation is apparent. Figure 52 is a photograph of this area.

Beyond the first 2,000-foot section of Reach No. 21, the beach narrows to widths ranging from 30 to 50 feet. The adjacent bluffs range from 5 to 35 feet in height with the greatest height at the eastern end of the study area. The upland is comprised of relic sand bars that are easily eroded. A typical portion of this beach is shown on Figure 53.

Figure 52. -- TYPICAL SHORELINE - WESTERN REACH NO. 21

Figure 53. -- TYPICAL SHORELINE - EASTERN REACH NO. 21

The small streams tributary to the Lake Superior in Reach No. 21 all trend to the east. However, the appearance of the sand spits lakeward of the streams would indicate this to be a temporary condition rather than a long-range trend. A typical section through this area is included as Figure 54.

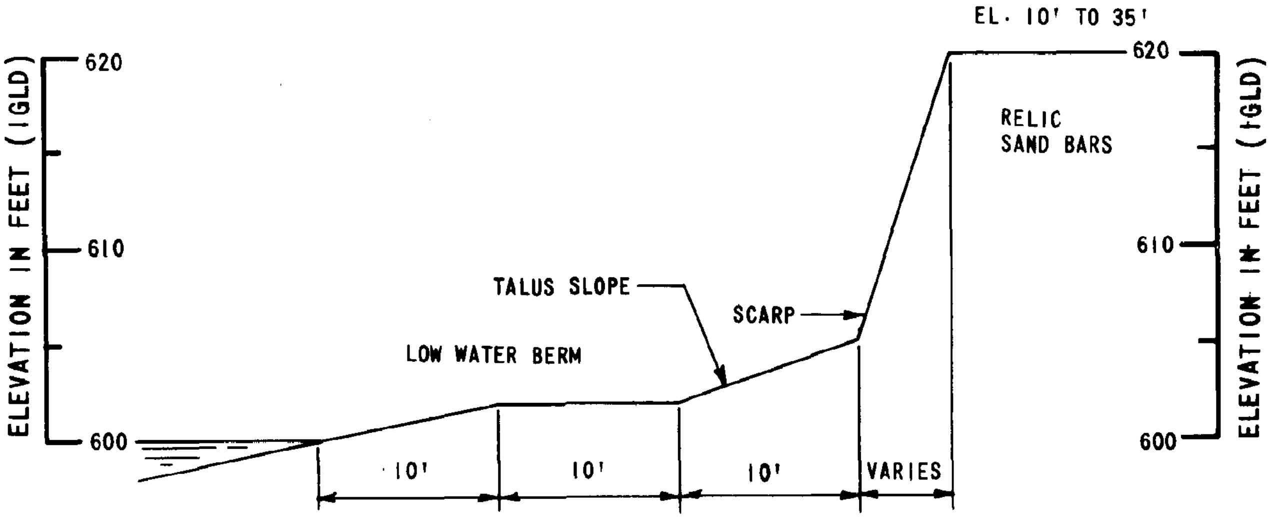


Figure 54. -- TYPICAL BEACH CROSS SECTION - EASTERN REACH NO. 21

Shoreline Developments

A recent questionnaire, completed by owners of property adjacent to the Lake Superior shoreline, shows a variety of building values ranging from cabins at $500 to homes valued at $20,000 and above. The average value of buildings within the study area is approximately $18,000. Shoreline development is expected to become more intense in the future, especially near Ontonagon as the demand increases for more recreational and building sites.

The greatest concentration of present development is in Reach Nos. 4 through 7 and 11 through 17. Also, Reach No. 2 has been moderately developed in the vicinity of the state park at the west end of Union Bay. Elsewhere, the study area is sparsely settled.

Existing buildings are, for the most part, summer homes along the beach and permanent residences concentrated near Silver City, Green, and Ontonagon. A few commercial structures such as motels are located in areas which will become endangered by erosion in the future.

Some highway construction close to the lake is also threatened by erosion. The most critical section is along State Highway 107 immediately east of Union Bay. Other affected locations have been described in the previous section of this report.

MECHANISMS OF EROSION

Rainfall

Rainfall contributes to shoreline erosion or accretion in several ways. The impact of falling raindrops on steeply sloped cliffs frequently erodes soft materials near the waters edge at a rate comparable to the more obvious effects of wave attack. Rainwater percolating through the ground adjacent to the lake front often initiates slides. Shorelines periodically become more susceptible to erosion due to the destructive forces of ice formation in rock crevices and between soil particles.

By far the most destructive influence of rainfall on shoreline erosion is a rise in lake levels caused by excessive precipitation. During a period of high lake levels, beaches, which normally protect the shoreline by causing waves to break at a distance, become inundated enabling waves to attack formerly protected areas.

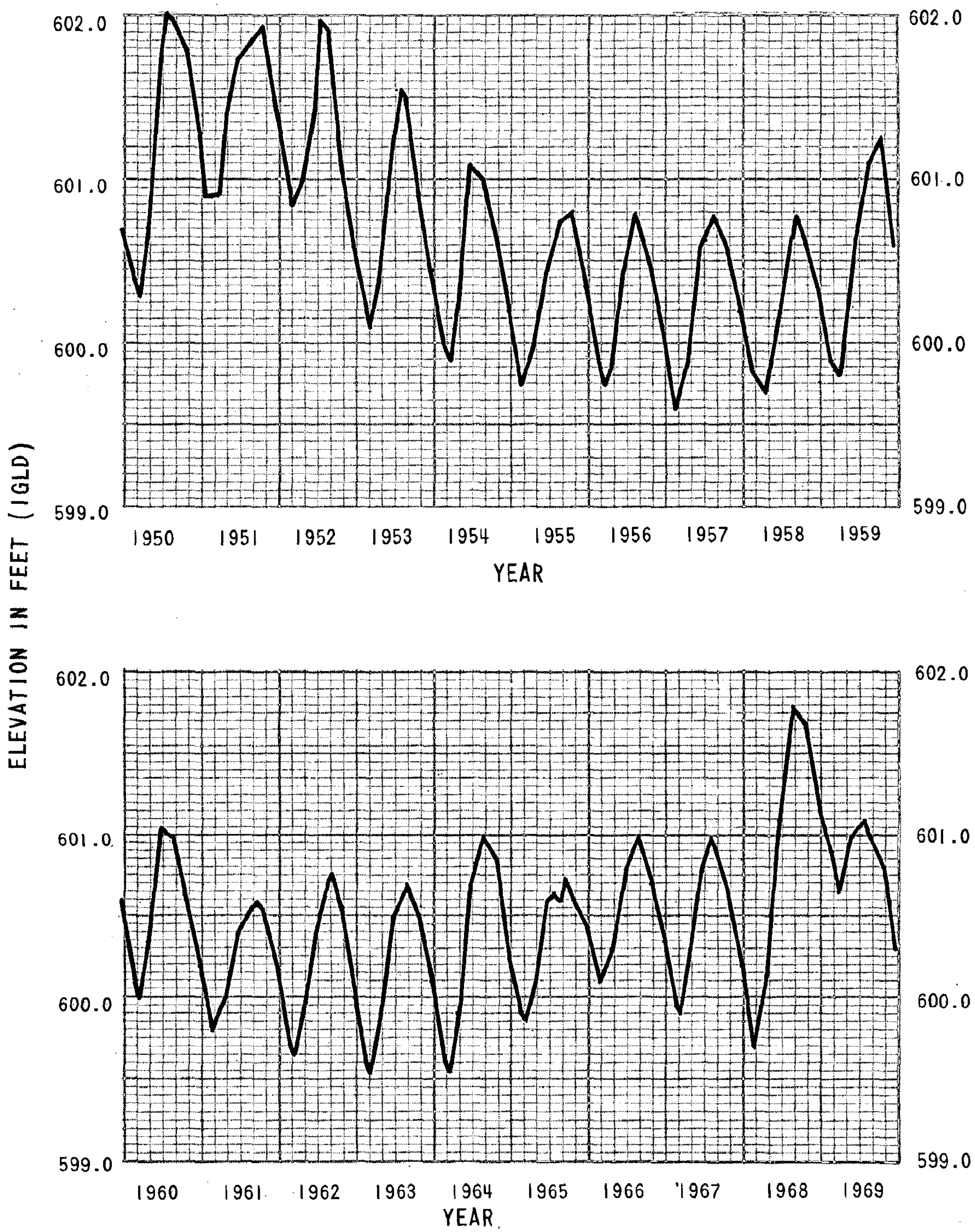
The influence of rainfall upon lake levels is demonstrated by a review of a recent period of high levels centered upon the year 1968. The average annual rainfall over the Lake Superior Basin for the period from 1900 through 1967 was 21.9 inches. During the ten-year period ending in 1967 this long term average was exceeded by about three percent. In the year 1968 recorded rainfall was 29.7 inches or about 36 percent higher than the long term average. Plate 3, which is extracted from the "Hydrograph of Monthly Mean Levels of the Great Lakes" produced by the U. S. Lake Survey, shows Lake Superior levels for the years 1965 through 1969. The lake level response to the high rainfall of the year 1968 is typical. Damages to the shoreline which occurred in 1968 are discussed subsequently in this report.

Experience of the response of the lake to precipitation and runoff has enabled the Lake Survey District, Corps of Engineers to predict levels for a few months in advance. These forecasts provide advance warning of exceptionally high levels which should be heeded by those with property subject to damage by severe erosion. Longer term forecasts, except for a general pattern, are not possible based upon present inability to predict meteorlogical events. As a basis for planning, it should be assumed that lake levels in the future may reach or exceed past record levels.

In an indirect way, rainfall can assist in shoreline accretion. Following a period of heavy rainfall, streams normally carry a heavy sediment load consisting of sand and gravel. This material is deposited along the coast near the mouth of the streams and serves to "nourish" the beaches forming erosion protection for the shoreline.

Wind and Waves

While wind alone contributes little to shoreline erosion, its action in forming waves constitutes the major factor in coast erosion. A secondary effect of wind influencing lake currents is of far less importance.



NOTE: STAGES REPRESENT MONTHLY MEAN LAKE LEVELS

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

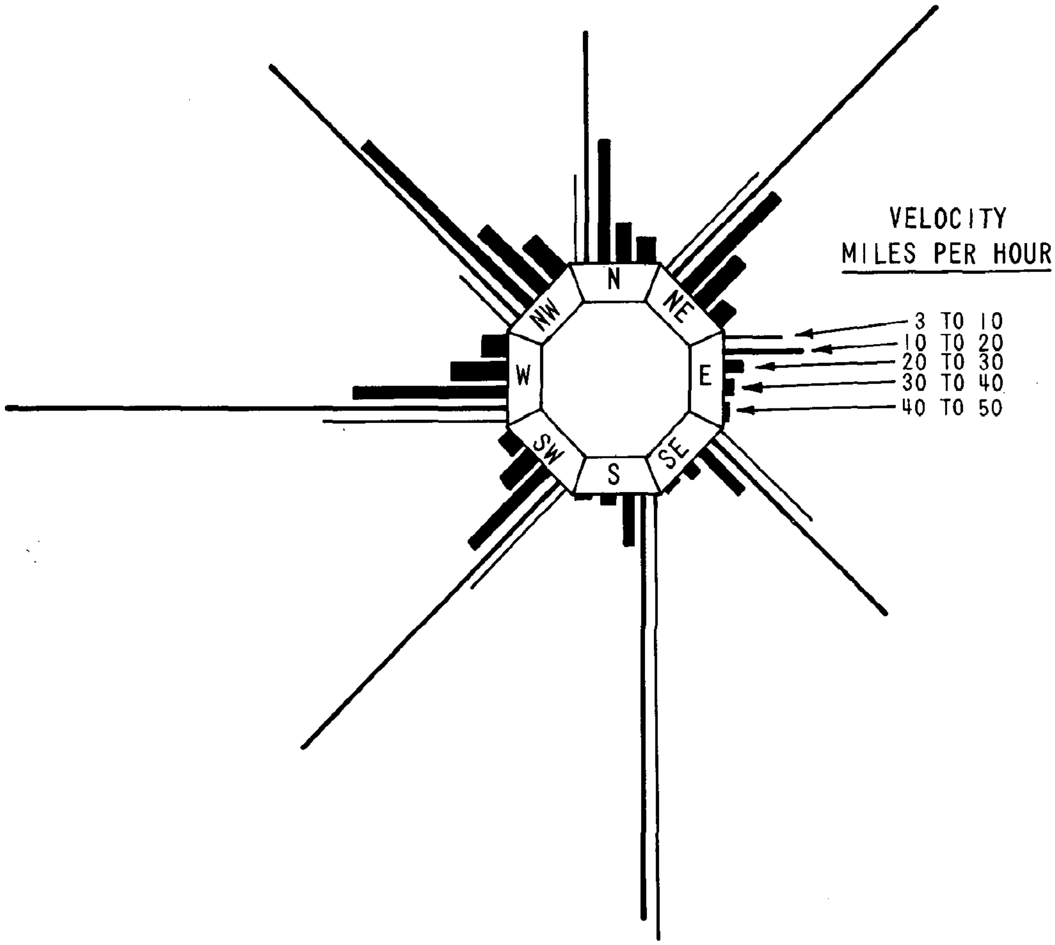
LAKE SUPERIOR STAGE HYDROGRAPH

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

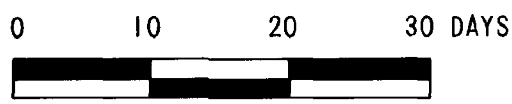
The closest wind recording station to the study area is at Keweenaw Waterway about 50 miles to the east. Results obtained at this location are considered representative of the study area. Plate 4 shows the wind rose based on the period 1911 to 1930. It is apparent that winds from every quadrant are represented. Winds blow from the west 32.5 percent of the time, from the north 24.4 percent of the time, from the east 14.6 percent of the time, and from the south 28.5 percent of the time. Maximum daily winds range between 10 and 20 miles per hour (mph) for about 50 percent of the time and exceed 20 mph for 26 percent of the time.

Wind generated waves travel in approximately the same direction as the wind. As the waves approach the shore they break and run up the beach carrying abrasive sand and gravel particles which grind away at any cohesive material with which they come in contact. This results in erosion near the water line. Sometimes, erosion of this type proceeds sufficiently fast to undermine an overlying cliff causing its collapse. Waves approaching at an angle to the coastline wash abraded particles in a zigzag pattern along the beach giving rise to the net transport of material know as "littoral drift."

The coastline of Lake Superior in the study area is oriented in a general west-southwest to east-northeast direction. Only winds coming from a direction north of this alignment are effective in generating waves which contribute to shore erosion in the area. The resultant effective energy of the contributing winds is from a direction approximately north 32 degrees west or slightly to the east of a line drawn normal to the general orientation of the coast. A slight general tendancy for littoral drift from the west to east is therefore to be expected with local reversal where the coast runs in a more southwesterly to northeasterly direction. Temporary reversal of the littoral drift may also occur during individual storms from the north and northeast.



DAILY MAXIMUM WIND DATA FROM KEWEENAW WATERWAY
LENGTHS OF RADIATING LINES INDICATE AVERAGE DURATION
IN DAYS PER YEAR THUS-



PERIOD 1911 TO 1930 INCL.

NO WIND DATA AVAILABLE AT ONTONAGON HARBOR

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

WIND ROSE

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

No records of accurate wave height measurements have been found for Lake Superior along Ontonagon County, however, historical descriptions of past storms report waves as high as an estimated 35 feet. Theoretical deep water wave heights have been calculated from consideration of wind velocity, duration, and length of fetch (open water) over which wind may act. The resultant data, as presented in Table 7, indicate a design deep water wave of 20 feet for the study area. As is apparent from historic records, waves of greater magnitude may occur, however, their occurrence would be very infrequent.

TABLE 7

DESIGN WAVES

	Wind			Computed Deep Water Wave		
Direction	Fetch miles	Velocity mph	Duration hours	Height feet	Length feet	Period seconds
N 80° W	112	65	4.4	20.0	522	10.1
NW	73	67	4.6	20.0	522	10.1
North	59	56	6.6	16.3	443	9.3
N 15° E	50	45	12.0	11.5	320	7.9
N 26° E	50	45	12.0	11.5	320	7.9

Source: "Review Survey, Lake Superior, Misery River, Michigan, Small Boat Harbor" by the Corps of Engineers dated April 6, 1970.

Deep water waves usually break well before they reach the shore. Smaller waves which continue to the shoreline are responsible for erosion damage. The height of the shallow water waves is dependent upon the type of shoreline as well as the magnitude of deep water wave. Assuming a stillwater lake level of Elevation 604.0 (maximum water elevation of the past plus two feet allowance for seiche) and a typical rocky shore profile as shown on Figure 55, the maximum waves to reach the shore will be about 3.4 feet high acting against the rocky cliff with a run-up to Elevation 606.3. Under similar conditions, but against a typical sandy beach (see Figure 56), maximum breaking waves to reach the shore will be about 3.3 feet high running up the sloping face of the beach to Elevation 607.3.

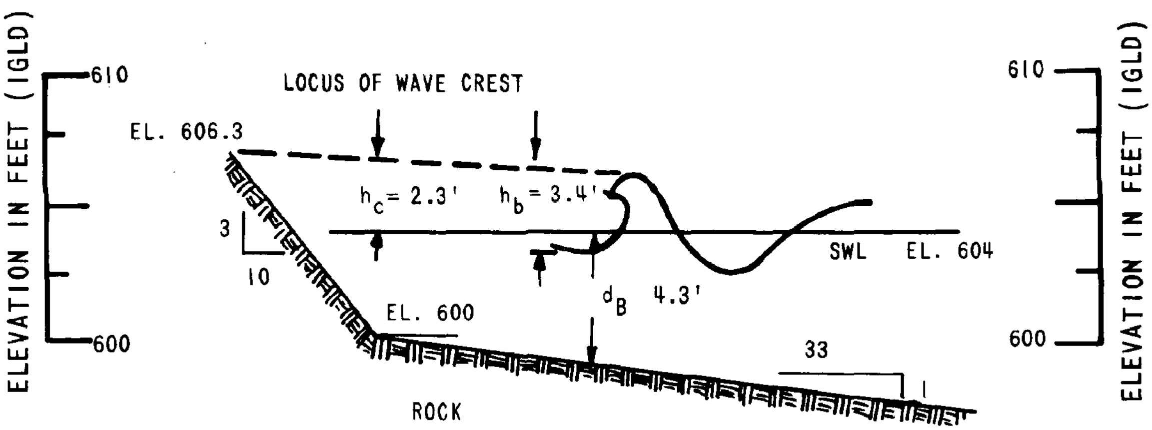


Figure 55. -- TYPICAL WAVE ATTACK - ROCKY SHORELINE

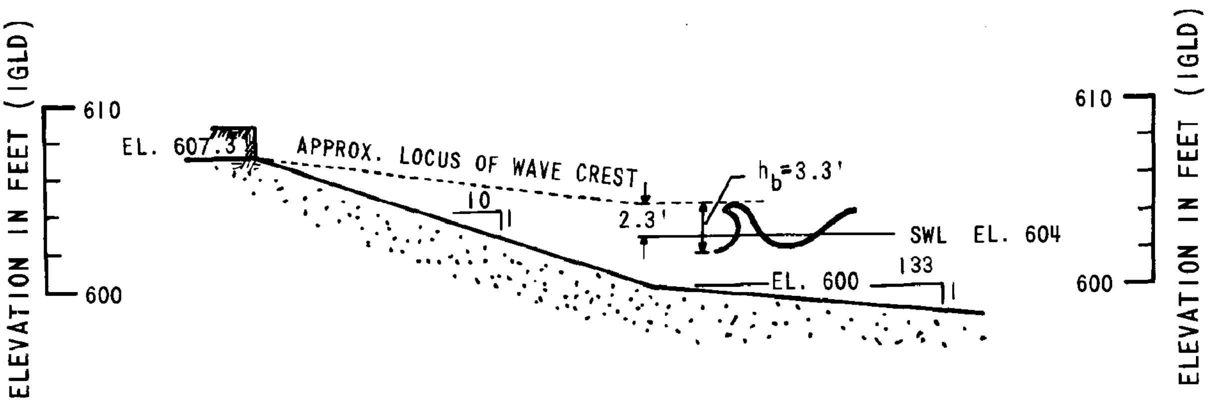


Figure 56. -- TYPICAL WAVE ATTACK - SANDY BEACH

Preliminary design of erosion protection facilities along the Ontonagon County coast may be estimated from the two cases described above. Protective works should generally be effective to about Elevation 607.0 with a more precise determination depending upon the actual profile of the coast line at the specific location.

Ice

The period of ice formation on Lake Superior differs each year depending on climatic conditions, however, it may be expected between early November and the middle of March.

Ice formation may periodically cause considerable damage to shorelines or shoreline structures in local areas, but the net effect of ice is generally beneficial. Wave formation is suppressed by an ice cover on the lake itself and protective ice ususally forms on the bank and adjacent structures. Ice piled on shore by wind and wave action does not, in general, cause serious damage to the shoreline.

Freezing and thawing tend to break up the laminated red sandstone formations along several reaches of shoreline within the study area. The result is the formation of a heavy shingle that protects the adjacent shore from erosion. In other reaches, freezing causes erodible banks to become more stable during winter months, however, the net effect of freezing and thawing is a degradation of the shoreline stability.

Lake Levels

The water surface elevation of Lake Superior is influenced by direct rainfall and runoff from tributary streams, discharge through St. Marys River, and evaporation losses. Since runoff and evaporation vary on a daily and annual basis, a pattern of irregular long term lake level fluctuations exists. Usually, however, low lake levels occur in the early spring with peaks following in July or

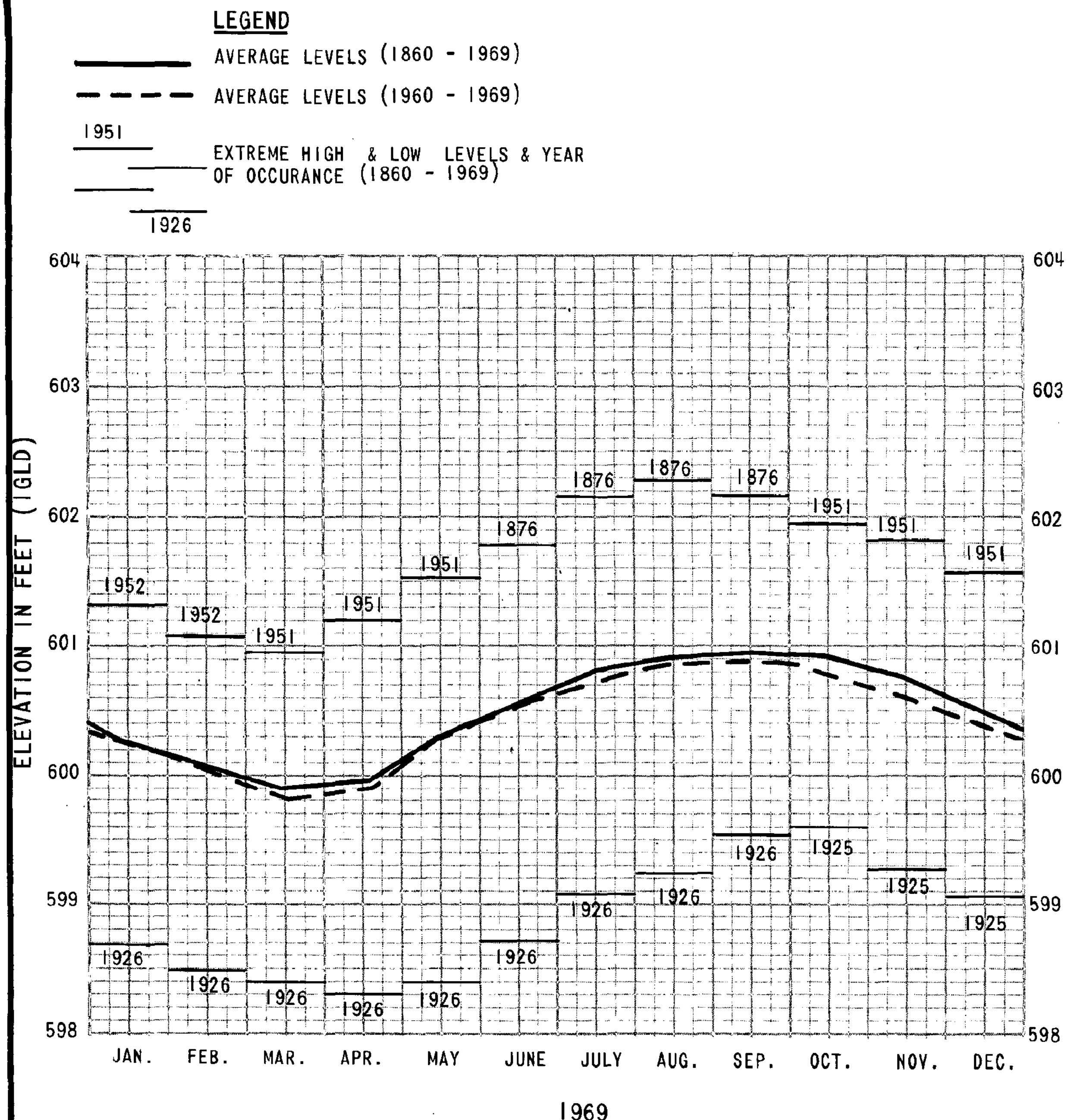
August. As discussed previously, the level is responsive to successions of wet or dry years. Plate 5, extracted from the "Monthly Bulletin of Lake Levels" published by the Lake Survey District of the Corps of Engineers, shows average and extreme levels of Lake Superior since 1860.

In 1921, improvements were made at the outlet from Lake Superior to control lake levels and increase discharge capacity. This consisted of a gated outlet control structure at Sault Ste. Marie and channel improvement in the St. Marys River. The question of level control of the Great Lakes is becoming more important as the effect of high lake levels upon erosion becomes more widely appreciated. It is apparent that the lakes cannot be considered individually, but must be regarded as a system. Increasing releases at a time of high water in Lake Superior may cause an increased problem downstream. Studies showing the economic effect of high levels in all the lakes will be of assistance in formulating plans for best use of the regulating capability of the Lake Superior outlet.

Local lake level variations often occur as the result of wind and sometimes barometric pressure differences. These uncontrollable elements have the effect of producing short period seiches in the lake resulting in level fluctuations from a few inches to two or three feet. Design for erosion protection should provide for recurrence of high average water levels of the past with an additional allowance of two or three feet to allow for these short period seiches. Seawalls and similar protective measures should extend to sufficient elevation to protect against likely wave action coincided with these high lake levels.

Geology of the Area

Bedrock consists of northward-dipping red, Lake Superior sandstone and highly laminated shale. To the west of Union Bay, these rise to form the front station of the Porcupine Mountains. Beneath



DEPARTMENT OF THE ARMY
ST PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

MEAN MONTHLY LAKE LEVELS

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

the sandstone and shale, the formation consists of conglomerate, lava flow, and felsite as shown on Figure 57.

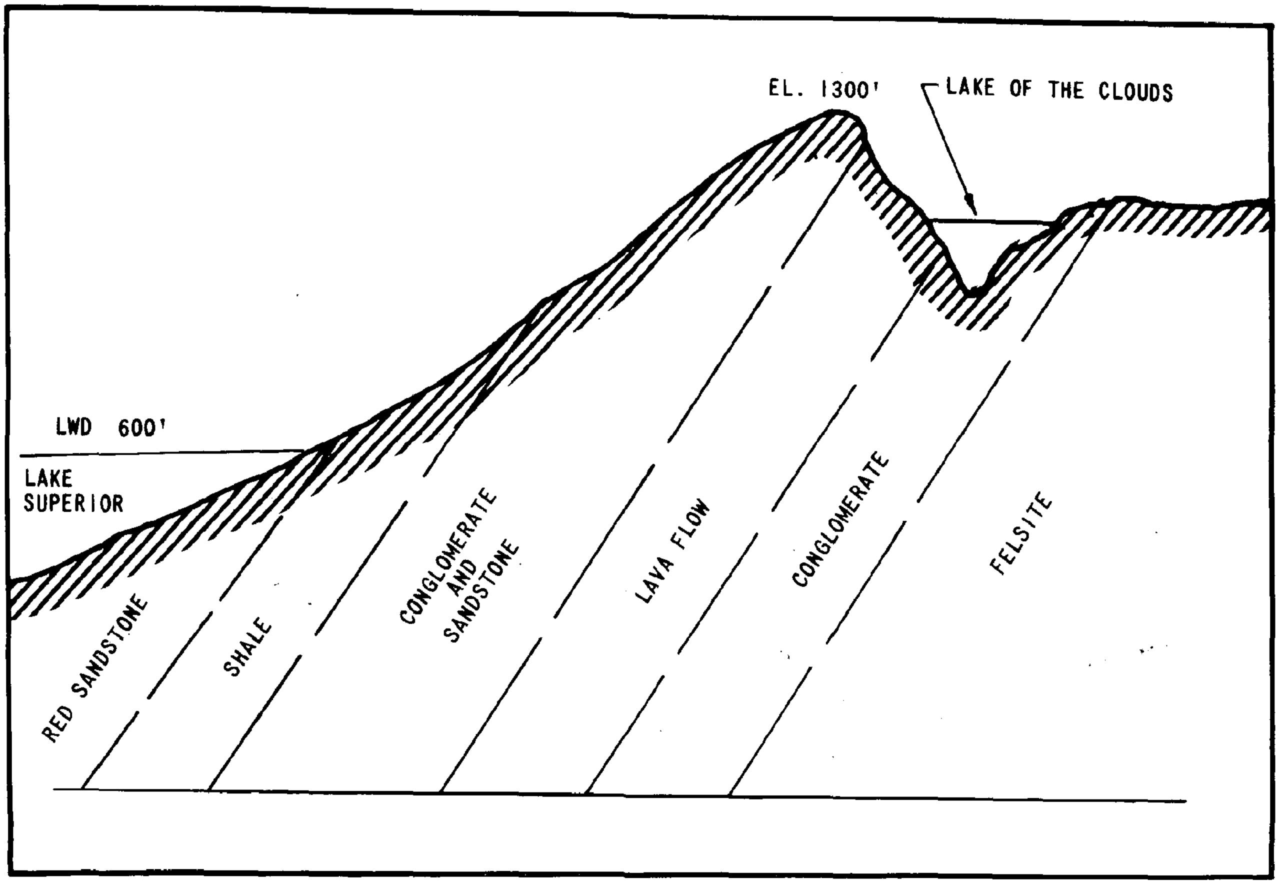


Figure 57. -- TYPICAL GEOLOGICAL SECTION - PORCUPINE MOUNTAINS

Throughout the study area these rocks form erosion resistant headlands. Between headlands, depressions in the sandstone, now filled with erodible relic dune material, have led to the formulation of shallow embankments. Also present are alluvial sands and red lacustrine clays.

Littoral Drift

Littoral drift, the mechanism by which beaches are eroded or built up is not only a result of erosion, but also a factor which influences erosion of an area. In the previous discussion of wind and waves, the presence of a weak overall tendency of littoral drift from west to east was predicted from an analysis of wind records.

No determinations of net littoral transport rates have been made. It should be noted that wind data indicate that the strongest movement of beach material will be offshore during periods of strong wave action followed by a return of material to the beach during periods of low wave activity.

One total barrier to littoral drift exists at the harbor at Ontonagon. Here, two parallel jetties have been constructed to help maintain a navigable river entrance. Interception of littoral drift from west to east has resulted in the building of an extensive beach to the west. A lesser beach is to be seen to the east of the jetties. This is formed during easterly gales, but is shielded from re-erosion by the jetties. The alignment of the beach deposited at the western jetty runs approximately N 40° E. This natural equilibrium angle is indicative of the angle at which beaches might form behind protective groins constructed in the area.

Beaches, such as those adjoining the Ontonagon Harbor, can only form when supplied with material from an updrift direction. Principal sources are rivers or rapidly eroding beach areas. Conversely, beaches may suffer by being starved of such materials. When this occurs the natural forces producing drift remove existing beaches without replenishing them. The net effect is erosion. No serious erosion is apparent for some distance downdrift (east) of the mouth of the Ontonagon River, possibly because the river itself constitutes a source of replenishment of materials intercepted by the jetties.

At some locations along the study area, deposits of sand and gravel on the beach are being mined as a source of construction materials. Each cubic yard of material so removed must be compensated for by erosion downdrift. These mining operations should be carefully regulated as their influence is frequently felt a considerable distance from the area of removal.

In many areas, erosion protection accompanied by enhanced attractiveness for recreational purposes is most economically accomplished by construction of groins to trap littoral drift. Beach building materials are not plentiful in the area and their transport rates are relatively slow. The possibility of groins "robbing" some downdrift use of littoral material should therefore be considered in all cases. Construction of groins should be regulated by a responsible authority who will carefully examine this aspect before a permit for construction is issued.

EROSION SITUATION

Shoreline Changes

The earliest maps which accurately depict the shoreline of Lake Superior in the study area were prepared from an 1855-65 "Survey of the N. & N.W. Lakes" by the Corps of Engineers. These maps have been used in conjunction with a 1950-56 series of U. S. Geological Survey 15-minute quadrangle maps and 1943, 1964, and 1970 aerial photographs to establish a history of shoreline erosion for Ontonagon County. The 1943 aerial photographs do not cover the entire study area and are, therefore, supplemented by 1964 photographs in the eastern portion.

Plates 15 through 23 show a 110-year history of shoreline changes plotted on reproductions of 1970 aerial photographs. An index of these aerial photographs is presented as Plate 14. The shore outlines, which indicate the waters edge, have been developed by comparative means using the available maps and aerial photographs discussed above. The accuracy of the 1860 outline is dependent upon the early maps which do not allow detailed reproduction of the shoreline. Later shore outlines are presented with more detailed accuracy. In addition to the past shore outline, Plates 15 through 23 include a projection of the probable shoreline in the year 2020.

Surveyed beach cross sections, typical of the various reaches of shoreline studied, are included in Plates 24 through 26. These cross sections provide an indication of the status of erosion or deposition of the present time. Location of each cross section is shown on the aerial photographs (Plates 15 through 23).

Erosion rates have been calculated from a comparative analysis of shoreline changes along the study area of Lake Superior. Losses of 50 to 100 feet of shoreline width since 1943 are not uncommon. In the last 27 years, extreme rates of erosion have amounted to an average of 4.0 feet per year at the embankment near the mouth of Pine Creek and 3.0 feet per year immediately east of Green. Erosion rates are often accelerated beyond these average values during individual years or especially during storm periods.

The maximum rate of accretion occurred adjacent to the Ontonagon Harbor entrance at an average of 8.0 feet per year. Since 1860, some accretion has occurred at Union Bay but this reach is currently experiencing erosion. Elsewhere along the coast, accretion is nonexistant except for localized temporary "build ups" occurring at river mouths. Rocky headlands have remained essentially unchanged during the past 110 years.

Existing Protective Structures

Approximately 1,000 feet of random stone seawall was constructed following the 1968 period of high lake level damage to protect State Highway 107 adjacent to Union Bay. A photograph of a section of this seawall was presented previously in this report as Figure 28. From examination of the form of construction used, it is anticipated that frequent damage of the seawall may occur when lake levels are high.

A number of private structures has been constructed particularly in the vicinity of Green and to a lesser extent near Ontonagon. Seawalls ranging in length from 100 to 250 feet have been constructed to a great variety of designs including concrete wall, precast concrete shapes, rock-filled timber crib, composite crib and concrete construction, concrete blocks, and miscellaneous mixtures of random stone, broken concrete, bricks, and old tires filled with concrete. Photographs of typical privately constructed seawalls are included on Figures 58 through 60.

Groins also have been attempted with almost invariable lack of success. Short groins, 10 to 15 feet in length, are common and these have been ineffective in trapping and maintaining beaches. They commonly suffer from lack of toe protection against scour which has led to their settlement and subsequent failure. Also, inadequate strength to withstand storm waves, inadequate height to prevent overtopping by storm waves, and lack of maintenance characterize the short groins.

Figure 58. -- CONCRETE AND ROCK SEAWALL

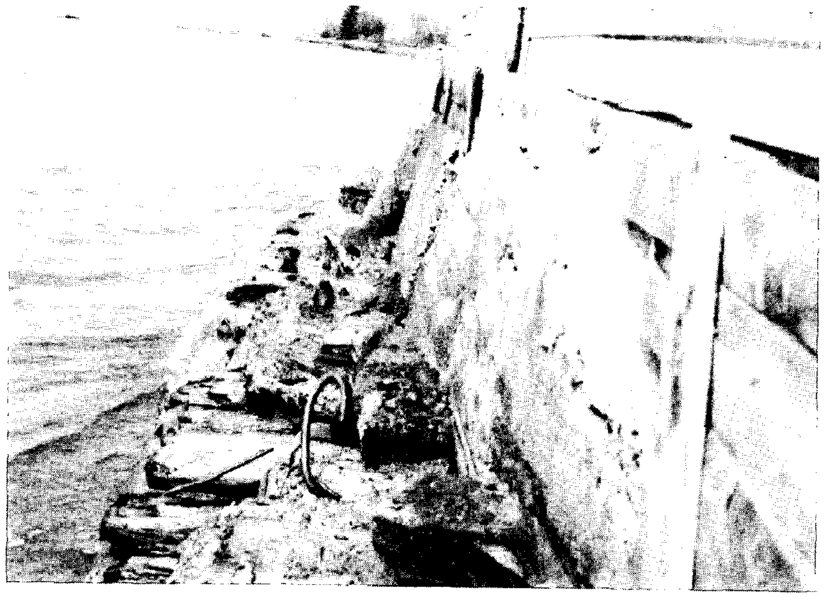


Figure 59. -- CONCRETE AND TIMBER SEAWALL

Figure 60. -- BROKEN CONCRETE RUBBLE "PROTECTION"

Generally, the privately constructed coast protection works are poorly designed and constructed and do not enhance the appearance of the area. Lacking support of similar construction on adjoining property they soon become isolated headlands vulnerable to destruction from the flanks.

The jetties at the mouth of the Ontonagon River are adequately designed with heavy corner stone to withstand wave action and with sufficiently high and massive shore ends to resist outflanking. The following photographs of this structure illustrate the type of construction necessary to be durable for this purpose. The heaviness of construction is in contrast to many privately constructed works in the area and the general appearance is far more satisfactory.

Figure 61. -- EAST ONTONAGON RIVER JETTY - SHORE END

Figure 62. -- EAST ONTONAGON RIVER JETTY - LAKEWARD END

STORM DESCRIPTIONS

Following are descriptions of known severe storms that have occurred on Lake Superior in the vicinity of Ontonagon County. These are based on field investigations, newspaper accounts, historical records, and other publications.

November 1913

Little information is available relating to the 1913 storm except for the following account from the book "Lore of the Lakes" by Dana Thomas Bowen:

". . . Thus it was on that Saturday, November 8th, of that year, as lake shipping battled what started to be just another early winter blow. Captains then had no way of knowing that this blow was going to be worse than any other that they had ever encountered.

" 'No lake master can recall in all his experience,' reported the Lake Carriers Association afterwards, 'a storm of such unprecedented violence with such rapid changes in the direction of the wind and its gusts of such fearful speed. Storms ordinarily of that velocity do not last over four or five hours, but this storm raged for sixteen hours continuously at an average velocity of sixty miles per hour, with frequent spurts of seventy and over.

" 'Obviously with a wind of such long duration, the seas that were made were such that the lakes are not ordinarily familiar with. The testimony of masters is that the waves were at least thirty-five feet high and followed each other in quick succession, three waves ordinarily coming one right after the other.

" 'They were considerably shorter than the waves that are formed by the ordinary gale. Being of such height and hurled with such force and such rapid succession, the ships must have been subjected to incredible punishment.

" 'Masters also relate that the winds and sea were frequently in conflict, the wind blowing one way and the sea running in the opposite direction. This would indicate a storm of cyclonic character. It was unusual and unprecendented and it may be centuries before such a combination of forces may be experienced again.'

"In the big cities that border the lakes, and throughout the surrounding country, land traffic was paralyzed. Communication and power lines were wrecked. Street and interurban cars were left stranded in the streets, stalled by the snow and the ice that formed on the wires and rails. Thousands of persons were marooned in whatever shelter they could find while the storm raged. Railroads abandoned trying to operate their trains. But to the men aboard ships on the lakes it was stark tragedy."

December 1968

A recent storm struck Lake Superior in December of 1968. The unusually high lake levels which existed during 1968 were a factor contributing to the intense shoreline erosion damage caused by this storm. Figures 63 through 67 include photographs showing some of the damage caused by the December 1968 storm.

The following are excerpts from a newspaper account which indicate the severity of the December 1968 storm.

THE ONTONAGON HERALD
Thursday, December 19, 1968
STORM SENDS LAKE ON RAMPAGE

"The severe storm which struck the Upper Peninsula last week caused the closing of all schools in Ontonagon County Friday morning, cancelled numerous meetings and basketball games, kept the County Road Commission on a round-the-clock schedule and sent Lake Superior on another rampage.

"A heavy downpour of rain Thursday turned into snow early Friday morning and continued well into Saturday. Winds with gusts of more than 50 miles per hour caused blizzard conditions and hazardous driving as there was a sheet of pure ice under the snow."

"Rampaging Lake Superior eroded more beach over a wide area, gouged deeply into Lakeshore property and felled numerous trees as the high waters washed them out by the roots."

"Water rose about 2.5 feet at Lakeshore Cabins, swept a canoe which was leaning against a cabin and floated it amid ice and other flotsam over 300 feet toward M-107 and left it resting about 50 feet from the highway.

"A truck driver who went over Highway M-107 Friday morning reported that waves from the lakes were coming over the highway near Union Bay, but the County Road said the highway is in no danger and two-lane traffic is being maintained. About a month ago the Michigan State Highway Department placed signs in this area warning drivers to proceed with caution."

Figure 63. -- SHORE EROSION SCENES IN ONTONAGON COUNTY - DECEMBER 1968

Top view is looking west toward the Porcupine Mountains from the Union River adjacent to Union Bay. The State Highway 107 sign gave way to Lake Superior shortly after this photograph was taken. Lower view shows the result of damages along this same section of highway.

Figure 64. -- SHORE EROSION SCENES IN ONTONAGON COUNTY - DECEMBER 1968

The man in the upper photograph is standing on State Highway 107 adjacent to Union Bay. Lower view shows erosion damage and debris washed ashore at a cottage near Green, Michigan.

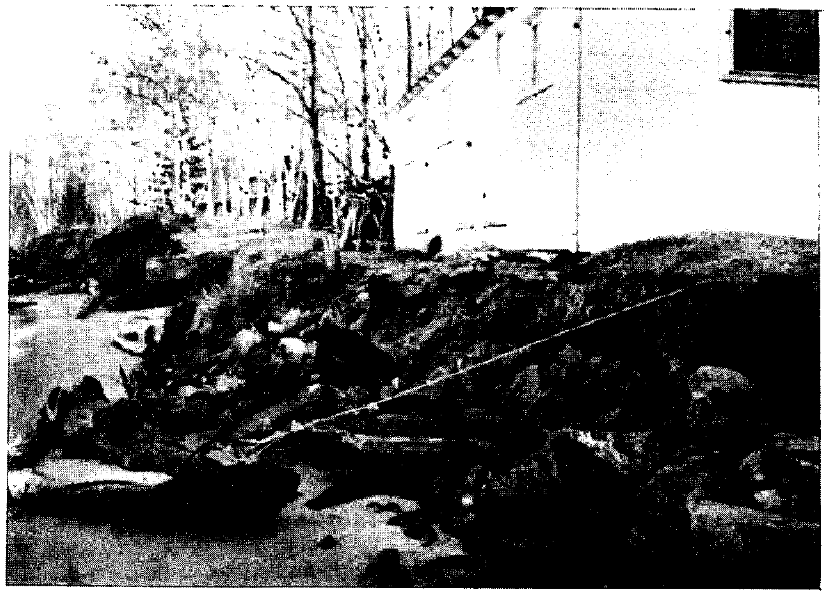


Figure 65. -- SHORE EROSION SCENES IN ONTONAGON COUNTY - DECEMBER 1968

Top view shows failure of locally attempted shore protection measures at a property west of Ontonagon. Bottom photograph was taken along the beach near the mouth of the Big Cranberry River. The large birch trees, which were uprooted by Lake Superior erosion, were located on the Wallace Jarvi property.

Figure 66. -- SHORE EROSION SCENES IN ONTONAGON COUNTY - DECEMBER 1968

Top photograph was taken at the Kirouac property at Green. Lake Superior has gouged deeply into this property and has undermined several cottages as well as destroyed trees. Lower view shows Lake Superior shoreline threatening a building approximately four miles west of Ontonagon.

Figure 67. -- SHORE EROSION SCENES IN ONTONAGON COUNTY - NOVEMBER 1968

This photograph was taken November 7, 1968, prior to the severe storm which occurred later that year. Damages shown at Township Park include uprooted trees as well as a swiftly diminishing beach caused by the high lake levels alone.

FUTURE SHORE EROSION

DESIGN STORM

The design storm for the Ontonagon County shoreline along Lake Superior is based on wave studies of the Misery Bay area completed by the Corps of Engineers in April 1970. Consideration for the design storm includes direction, velocity, and duration of winds to give maximum heights of deep water waves. Results of these studies, which were presented previously in Table 7, show a design deep water wave height of 20 feet which would occur with wind directions oriented from the northwest quadrant between N 45° W and N 80° W. The design wind velocity would be 65 to 67 miles per hour for a duration of 4.4 to 4.6 hours.

As the deep water waves approach the shore, they break and form smaller waves. The maximum height of shallow water waves which would be expected to reach the shore is 3.3 to 3.4 feet depending on the type of coast line. Figures 55 and 56 show sketches of typical waves which would confront rocky shorelines and sand beaches during the design storm.

PREDICTED SHORELINE EROSION

Experience has demonstrated that the beach zone along Lake Superior is constantly in a state of adjustment due to the effect of lake levels, storm waves, and shore currents. With changes in the action of these agents seasonally and during storms, the shoreline changes its location, sometimes eroding or receding landward and at other times accreting or advancing lakeward. Like the flood plain which is a normal part of the river during flood periods, a part of the low areas along a shoreline are really a part of the lake during high stages.

Future shoreline changes have been predicted for the study area in Ontonagon County. In general, these forecasts assume erosion and accretion rates to continue in the future as they have in the recent past. This is considered to be a valid approach assuming no major changes are introduced to disturb the current trend.

Plates 15 through 23 show the projected shoreline for the year 2020. Plate 14 is an index map of the individual shoreline erosion maps. Local variation from the predicted shoreline may occur because of individual efforts toward shoreline protection or unknown geological formations. More extensive changes from the present trend may be caused by uncontrolled mining of beach materials, alterations within the drainage basin which will affect the sediment load of streams emptying into the lake, and construction of major erosion control facilities. Past records show that erosion is far more prevalent than accretion and therefore, the predicted shoreline for 2020 is, in most cases, farther inland than the present shoreline.

HAZARDS OF SHORELINE EROSION

Shoreline erosion has the potential of creating serious disasters. Loss of life and personal property and destruction of buildings, roads, and trees may be attributable to shoreline erosion. Land which is eroded by the lake represents a considerable loss not only to the property owner but also as reduced tax revenue for governing agencies.

Along the Lake Superior shoreline of Ontonagon County, severe damage has resulted from past erosion and considerably greater potential damage may occur in the future. Although there are no large population centers located in the study area, many of the homes, resort developments, roads, and other facilities which are located near the shoreline are subject to being destroyed or damaged by shoreline erosion.

SUGGESTIONS AND SUMMARY

REMEDIAL MEASURES FOR BEACH EROSION

Two possible approaches are available for coping with erosion problems in Ontonagon County. One would be to limit erosion losses by controlling developments near the shoreline. This is discussed subsequently in the "Guidelines for Use of the Flood Plain and Shoreline" section of this report. The second approach involves erosion control. Several alternative means for arresting the current erosion problem are discussed below.

One method which is often applicable for sparsely settled areas involves protecting only those sections of beach which have been developed or are otherwise considered relatively valuable. In the undeveloped reaches, erosion is allowed to continue unchecked. This method may have application in the portions of Ontonagon County which are relatively undeveloped. In conjunction with such an approach, restrictions should be instituted to control development in the unprotected areas.

The three most economical plans for preventing shoreline erosion in Ontonagon County include lake level regulation, prohibiting mining of beach materials, and controlling developments on the beach. Of the three, lake level control would be the most influential in reducing shoreline erosion, particularly on a short-term basis.

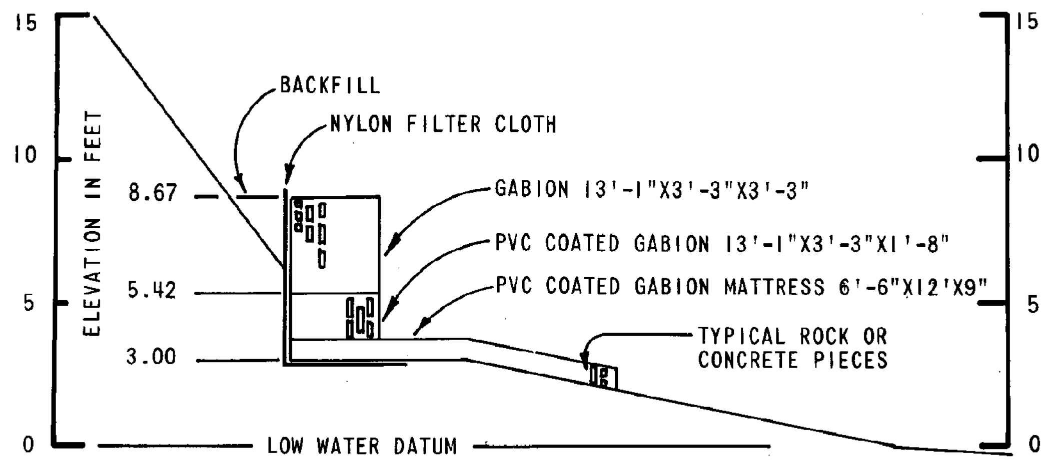
Protective measures are also available to help stabilize the shoreline. Groins may be applicable at some locations but, because of the shortage of littoral material in the area, they generally should not be employed. For approved uses, groins should be of sufficient length to retain the derived beach which will form at a pre-determined angle to the present shoreline.

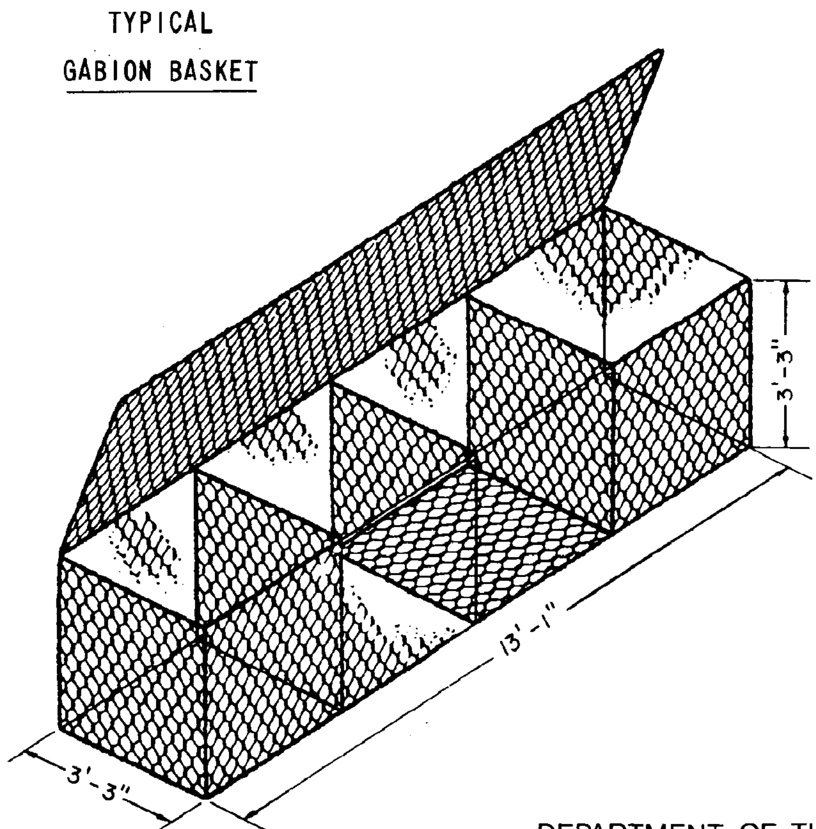
Groins should be of adequate height at the shore end to confine a beach of sufficient width to absorb wave run-up and be of adequate design to withstand toe erosion and wave forces. The method of original filling of groin systems with beach material must be considered as well as possible effects of robbing downdrift beaches of their natural replenishment.

Beach formation by the supply of additional materials artificially is feasible in some areas. Beaches downdrift from points where the material is introduced become enlarged as the supply of material exceeds the natural transport rate. Thus, wider protective beaches may be constructed without resorting to groins. Provision for the continuation of supplying beach nourishment materials is a necessary part of such a plan. Indications are that suitable beach building materials are not readily available in the area and the necessity of transporting them a considerable distance would not be feasible.

Seawalls appear to be the best suited method of coast protection for the area. For seawalls to be effective, they must be continuous over long reaches of coast line. In addition, they must be sufficiently high to prevent serious erosion by wave overtopping and heavy enough to withstand wave action and soil pressures. A filter should be provided to prevent leaching of soil through the wall. Toe protection is essential to prevent failure by undermining. Typical designs which might be used successfully in the area are shown on Plates 6 and 7.

The costs of the two types of seawall illustrated on Plates 6 and 7 are about equal. Gabion construction has become recognized as a method well adapted for construction by individual home owners but should be integrated with protective measures employed by neighboring property owners. The polyvinyl chloride (PVC) wire





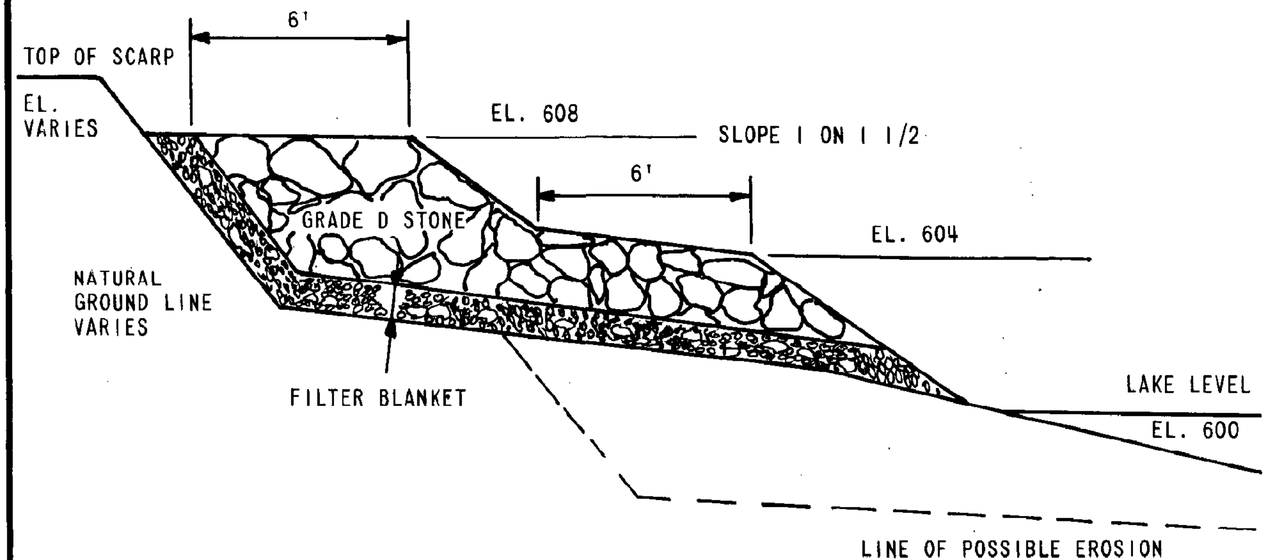
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

GABION CONSTRUCTION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

NOTE: GRADED STONE 430 LBS. TO 3.5 TONS
FILTER STONE 10 MM TO 25 LBS.
(QUARRY WASTE - SHOVEL RUN)

SCALE: 1" = 5'



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

TYPICAL ROCK SEAWALL

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

mesh basket which forms the gabion is filled with stone of sufficient size to be retained by the mesh. The completed gabion is then sufficiently massive to resist wave action but retains flexibility so that it is not easily destroyed.

Occasionally, offshore breakwaters are constructed in deep water to prevent waves from attacking the shoreline. These must be of very massive construction to withstand the larger waves to be encountered in the deeper water. Use of offshore breakwaters is seldom economically justified; they do not appear to have application in this area.

It may be concluded that successful administration of the coast cannot be left to private initiative. Co-ordination plans must involve long reaches of coast line. The optimum approach would also include regulated development on the adjacent lake frontage as discussed subsequently.

GUIDELINES FOR USE OF THE FLOOD PLAIN AND SHORELINE

Man has been building on and occupying the flood plains of rivers and streams since the coming of the pioneer settlers. The steams first provided transportation and water supply. Later, mill dams were built and early highways and railroads were constructed along the gentle valley grades. Today, the continuing growth of cities results in ever increasing encroachment on the flood plains.

The increase in flood hazards and flood damages, despite the expenditure of billions of dollars of tax funds for the construction of flood control works, has led to a new approach to the reduction of these hazards and damages. This involves exercise of control over the land lying adjacent to the stream through the planned management and development of flood hazard areas. The flood plain management program can prevent the creation of new flood hazard areas if fully integrated into the comprehensive land use and development plan of an area and enforced by means of appropriate zoning, subdivision, and building regulations. While flood plain areas probably never can be considered flood free, planning will allow selection of the type of development which is consistent with the flood risk. Also, it will allow a reasonable level of protection to be built into a project during initial construction.

Regulation of the flood plain can be carried out by a variety of means--encroachment lines, zoning ordinances, subdivision regulations, and modifications or additions to building codes. These methods will be described subsequently in some detail. However, it is not within the purpose of this report to recommend the specific technique to be used. Flood plain regulations are the responsibility of State and local governments, and these report data are provided to furnish a basis for appropriate regulatory action. The basic data in this report can be used in conjunction with comprehensive plans to develop a reasonable and desirable plan for use of flood plain land along the Ontonagon River and the Lake Superior shoreline in Ontonagon County.

Fortunately, the need for flood plain planning has been recognized by local interests. This means that future damages in the study area can be reduced at little or no cost to the taxpayer by the enactment and enforcement of flood plain regulations. The flood data in this report, together with the planning program for future land use, will enable State and local interests to minimize flood damage risks.

Flood plain management may also include other methods which are helpful, particularly in special localized areas. These include park and open space developments, evacuation, urban redevelopment, flood proofing, tax reductions, and warning signs.

Several approaches are also available for regulation of developments along shorelines subject to erosion damage. Primarily, zoning ordinances and regulation of beach nourishment are considered applicable for this study area.

Encroachment Lines

A designated floodway is the area of channel and those portions of the flood plains adjoining the channel which are reasonably required to carry and discharge the flood flow of a specific flood without unduly raising upstream water surface elevations. Encroachment lines or limits are the lateral boundaries of this floodway. They are two definitely established lines, one on each side of the river. Between the encroachment lines no construction or filling should be permitted which will cause an impedance to flow.

If possible, encroachment limits should be established before extensive development has taken place in order that costly clearance of existing structures may be avoided. Final choice of the magnitude of the flood, which will determine the size of the floodway, is a matter for state and local decision.

Zoning

Zoning is a legal tool used by cities, villages, and counties to control and direct the use and development of land and property within their jurisdiction. Division of a municipality or county into various zones should be the result of a comprehensive planning program for the entire area, with the purpose of guiding its growth. The planning program, as such, has no legal status. Zoning is a legal tool that is used to implement and enforce the details of the planning program. Its objectives are the conservation of property value and the achievement of the most appropriate and beneficial use of available land.

Flood plain zoning is not a special type of ordinance, but merely another set of provisions which can be incorporated into a comprehensive zoning ordinance so that flood damage can be minimized. Zoning regulations may be used in lieu of encroachment laws as well as a supplement to them. Designated floodways may be zoned for the purpose of passing flood waters and for other limited uses that do not conflict with that primary purpose. The ordinance may also establish regulations for the flood plain areas outside the floodway, such as designating elevations above which certain types of development must be constructed.

Zoning for shoreline erosion control involves a planning program for minimizing property damage along Lake Superior. A "set back" zone established along the lake front would define the area subject to erosion damage within a specified number of years.

Development within the zone would be restricted to low value investments with the developer fully aware of the potential damage. The use of portable facilities in the potential erosion zone may also be considered. Buildings, roads, or other permanent facilities should not be constructed within a specified safety distance from the projected shoreline.

The required technical data for institution of shoreline zoning are included in this report in the form of a projected shore outline for the year 2020. Projections further into the future will be required periodically to keep the zoning ordinances current.

Subdivision Regulations

Subdivision regulations are used by local governments to specify the manner in which land may be subdivided within the entire area under their jurisdiction. Regulations may state the required width of streets, requirements for curbs and gutters, size of lots, elevation of land, freedom from flooding, size of floodways, and other points pertinent to the welfare of the community. It has been found that responsible subdividers favor such regulations because they discourage land speculation and prevent unscrupulous competition from other subdividers who might develop flood hazard land with less than minimum desirable standards. Experience has also shown that various municipal costs are reduced during flood periods and that the annual maintenance required for streets and utilities is minimized. Subdivision regulations provide an efficient means of controlling development in areas which are presently undeveloped. By introducing such regulations early in these areas, planned flood plain development can take place without being hampered by nonconforming uses.

Building Codes

The primary purpose of building codes is to set up minimum standards for controlling the design, construction, and quality of materials used in buildings and structures within a given area, so that life, health, property, and public welfare are safeguarded. Since it may not be practicable to prevent the location of any building in all areas subject to flooding, building codes can be used to minimize structural and consequential damages resulting from flood velocities and inundation. Some of the methods adaptable to building codes are:

(1) Prevent flotation of buildings from their foundations by specifying anchorage.

(2) Establish basement elevations and minimum first floor elevations consistent with potential flood occurrences.

(3) Prohibit basements in those areas subject to shallow, infrequent flooding.

(4) Require reinforcement to withstand water pressure or high velocity flow and restrict the use of materials which deteriorate rapidly in the presence of water.

(5) Prohibit equipment that might be hazardous to life when submerged. This includes chemical storage, boilers, and electrical equipment.

Regulation of Beach Nourishment

Beach nourishment is provided for by an inflow of sediment to the shoreline and subsequent transport along the shoreline. As discussed below, any alteration of either the supply of sediment or its transport may affect shoreline erosion. Regulation of such changes is essential to insure the most economical use of the shoreline.

Sediment inflow to the shoreline along Ontonagon County is primarily provided by streams emptying into Lake Superior. Any alteration of the sediment transport by the stream, such as reservoir construction, may seriously reduce the sediment supply to the beach. The economic aspects of additional erosion losses should be considered in evaluating the economical justification for all stream improvements proposals.

The construction of groins, while improving a limited shoreline reach, may increase erosion in adjacent, downdrift areas by decreasing the natural inflow of littoral drift. In the evaluation of groins, or any project which acts as a littoral drift barrier, consideration must be given to the effect of this decrease of littoral material in the downdrift area.

Currently, beach materials are being mined from the Ontonagon County shoreline for construction use. Regulations are needed to restrict this practice because of the potential erosion which may occur downdrift of the mining area.

PERTINENT FEDERAL AND STATE LAWS

Existing Federal Laws on Beach Erosion Control and Lake Inundation

The Federal Government's role in shore erosion control is defined in the provisions of Public Law 826, 84th Congress, approved July 28, 1956, as amended by the River and Harbor Act of 1962 (PL 87-874), approved October 23, 1962, and as further amended by the River and Harbor Act of 1965 (PL 89-298), approved October 27, 1965. Under this statute the Corps of Engineers participates in the solution of shore erosion problems by making studies of eligible shorelines entirely at Federal expense. The present policy for Federal participation in the cost of works for shore protection applies, generally, to publicly owned shores. Privately owned shores may be eligible for Federal assistance only if there are significant public benefits arising from public use or from protection of nearby public property, provided that the protective works are economically justified.

The Corps of Engineers also conducts beach erosion control surveys or reviews and updates previous reports on the basis of individual directives from the U. S. Congress. The directives are in the form of either a resolution of the Public Works Committee of the Senate or the House or a separate item in a public works authorization bill. The Soil Conservation Service, Department of Agriculture has broad authority to undertake studies for upland watershed protection. These studies deal primarily with means of reducing flood flows into the Great Lakes.

The provisions of Section 111 of the River and Harbor Act of 1968 authorizes the Corps of Engineers to investigate, study, and construct projects for the prevention or mitigation of shore damages attributable to Federal navigation works. Investigation of the feasibility or desirability of work under this authority must be formally requested by a state, county, or other properly constituted local authority.

Federal Role in Beach Erosion Research

Public Law 166, 79th Congress, authorizes the Chief of Engineers through the Coastal Engineering Research Center to make general investigations with a view to preventing erosion of the shores of the United States by waves and currents and determining the most suitable methods for protection, restoration, and development of beaches. These general studies are for the purpose of developing or determining physical phenomena, techniques, principles, and procedures related to the protection, restoration, and development of beaches and shores. They provide the technical "know-how" to assist in arriving at sound, economical solutions to shore erosion problems generally. They do not result in the formulation of specific plans of protection or remedial works for a particular locality, since a separate study is required to develop such plans for each locality. General investigations are Federally financed and are initiated by the Chief of Engineers through the Coastal Engineering Research Center.

Emergency Flood and Coastal Storm Activities

The authority for Federal assistance in emergency flood and coastal storm activities is set forth in Public Law 99-84 (33 United States Code 701n) as amended by Section 206 of the Flood Control Act approved October 23, 1962; and in Section 9 of the Flood Control Act approved June 15, 1936 (33 U.S.C. 702 g-1). Preceding and during flood and coastal emergencies, the primary missions of the Corps of Engineers are authorized as follows:

(1) Preserve Federally owned and maintained flood control works and other facilities operated by the Corps of Engineers.

(2) Furnish appropriate technical assistance to state and local authorities upon request, advising them in their efforts to maintain the integrity of flood control works and Federally authorized shore and hurricane protection projects under their jurisdiction.

(3) If responsible state or local authorities are unable to cope with the flood or coastal storms situation, direct Federal assistance may be provided either by supply of needed materials or equipment or by undertaking Federal flood fighting or emergency protection.

The Federal Disaster Act of 1950 (Public Law 875-81) authorizes Federal assistance to state and local governments in a major disaster. A major disaster is defined as any "flood, drought, fire, hurricane, earthquake, storm, or other catastrophe which, in the determination of the President, is or threatens to be of sufficient severity and magnitude to warrant disaster assistance by the Federal Government to supplement the efforts and available resources of state and local governments in alleviating the damage, hardship, or suffering caused thereby.

State Agencies Concerned with the Beach Erosion Problem

Several state agencies have been given certain responsibilities related to beach erosion problems. Although none of these agencies is authorized to provide financial help to property owners, they are able to supply information and advice on matters pertaining to this problem.

In Michigan, the 1949 Legislature conferred certain limited powers and duties with respect to this problem upon the Water Resources Commission. A section of this act designates the Commission as the state agency to cooperate and negotiate with other governments, governmental units, and agencies thereof in matters concerning the water resources of the state, including, but not limited to, flood control and beach erosion control.

During 1952, the Michigan Legislature passed three acts with permit some participation of counties and townships in beach erosion problems. These are described in the following paragraphs.

Public Act No 42, P.A. of 1952, is an amendment to Section 1 of the county rural zoning enabling act, making it possible for county boards of supervisors of those counties fronting on the Great Lakes to establish appropriate set-back or building lines in areas outside of incorporated villages and cities. This is for the purpose of protecting individuals or groups from building in locations that are subject to inundation or erosion.

Public Act No. 43, P.A. of 1952, is an amendment to the special improvements act for townships and villages, Act 116, P.A. of 1923. This amendment permits the construction of beach and soil erosion control projects by such agencies on a special assessment basis.

Public Act No. 44, P.A. of 1952, is an act which gives all political subdivisions authority to make beach erosion studies either independently or in cooperation with other political subdivisions or any agency of the Federal Government. This bill also opens the way for Michigan political subdivisions to qualify for Federal assistance, should they care to seek it in connection with the investigating and planning of works for beach protection.

State Flood Plain Management Program

In recognition of the many problems associated with flood plain development, the State of Michigan has enacted the following two laws since January 1, 1968, which regulate such development:

Act 288, (Plat Act), Public Acts of 1967, which establishes minimum standards for subdividing land and for new development for residential purposes within flood plain areas. This act requires that preliminary plats be submitted to the Water Resources Commission for review and determination of flood plain limits. Upon completion of review and establishment of flood plain limits, the preliminary plat may be approved and minimum building requirements specified.

Act 167, (Flood Plain Control Act), Public Acts of 1968, which requires that a permit be obtained from the Water Resources Commission before filling or otherwise occupying the flood plain or altering the channel of any watercourse in the state. The purpose of this control is to assure that the channels and the portion of the flood plains that are the floodways are not inhabited and are kept free and clear of interference or obstruction which will cause undue restriction of flood carrying capacities.

It is important to note that these laws are intended to be minimum requirements only. Although the power to zone, which carries with it police powers for enforcement of zoning provisions, rests initially with the State, Michigan has delegated this authority to the smallest governmental entity. Michigan strongly encourages local governmental units to adopt reasonable regulations, which equal or exceed State minimum requirements, to guide and control development in flood hazard areas. It is believed that such joint State-local regulations will provide the most effective and satisfactory means of regulating flood hazard areas.

GLOSSARY OF TERMS

Beach Erosion. The carrying away of beach materials by wave action, littoral currents, or wind.

Beach Width. The horizontal dimension of the beach as measured normal to the shoreline.

Cross Section of Beach. The intersection of the ground surface in the beach zone with a vertical plane.

Discharge. The quantity of flow in a stream at any given time, usually measured in cubic feet per second (cfs).

Fetch. The continuous area of water over which the wind blows in essentially a constant direction.

Flood. An overflow of lands not normally covered by water, that is used or usable by man. Floods have two essential characteristics: the inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, ocean, lake, or other body of standing water.

Normally a "flood" is considered as any temporary rise in stream flow or stage, but not the ponding of surface water, that results in significant adverse effects in the vicinity. Adverse effects may include damages from overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions, or other unfavorable situations by deposition of materials in stream channels during flood recessions, rise of ground water coincident with increased stream flow, and other problems.

Flood Crest. The maximum stage or elevation reached by the waters of a flood at a given location.

Flood Peak. The maximum instantaneous discharge of a flood at a given location. It usually occurs at or near the time of the flood crest.

Flood Plain. The relatively flat area or lowlands adjoining the channel of a river, stream, or watercourse; or ocean, lake, or other body of standing water, which has been or may be ocvered by floodwater.

Flood Profile. A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above the mouth of a stream of water flowing in an open channel. It is generally drawn to show surface elevation for the crest of a specific flood but may be prepared for conditions at a given time or stage.

Flood Stage. The stage or elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Head Loss. The effect of obstructions, such as narrow bridge openings or buildings, that limit the area through which water must flow, raising the surface of the water upstream from the obstruction.

Height of Wave. The vertical distance between a crest of a wave and the preceding trough.

Hydrograph. A curve denoting the discharge or stage of flow over a period of time.

Intermediate Regional Flood. A flood having an average frequency of occurrence in the order of once in 100 years, at a designated location, although the flood may occur in any year. It is based on statistical analyses of stream flow records available for the watershed.

Left Bank. The bank on the left side of a river, stream, or watercourse, looking downstream.

Littoral Drift. The material moved in the shore zone under the influence of waves and currents.

Low Steel. The lowest point of a bridge or other structure over or across a river, stream, or watercourse that limits the opening through which water flows.

Right Bank. The bank on the right side of a river, stream, or watercourse, looking downstream.

Run-up. The vertical height above still water level that the rush of water reaches following the breaking of a wave.

Seiche. A periodic oscillation of a body of water thought to be initiated chiefly by local variations in atmospheric pressure aided in some instances by winds and tidal currents.

Standard Project Flood. The flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40 to 60 percent of the Probable Maximum Floods for the same basins. Such floods, as used by the Corps of Engineers, are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous.

Still Water Level. The elevation of the water surface if all wave action were to cease.

AUTHORITY, ACKNOWLEDGMENTS, AND INTERPRETATION OF DATA

This report has been prepared in accordance with the authority granted by Public Law 86-645 (Flood Control Act of 1960).

* * *

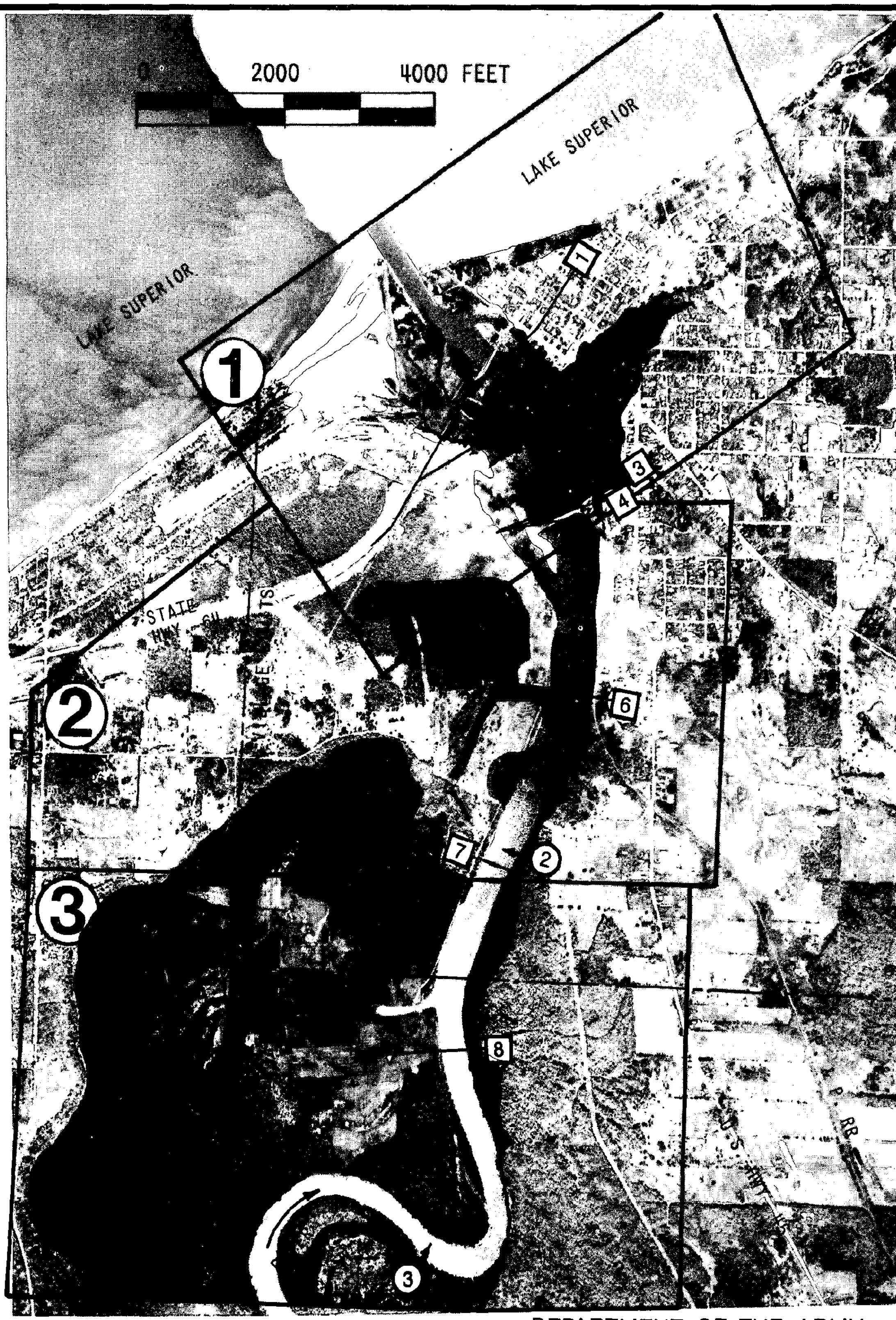
Assistance and cooperation of the U. S. Weather Bureau, U. S. Geological Survey, Michigan State Highway Department, Ontonagon County, Village of Ontonagon, and private citizens in supplying useful information are appreciated.

* * *

This report presents the local flood and shore erosion situation for the Village of Ontonagon, Michigan, and Ontonagon County, Michigan. The St. Paul District of the Corps of Engineers will provide, upon request, interpretation and limited technical assistance in application of data presented herein.

* * *

This report was prepared by Stanley Consultants, Inc., Muscatine, Iowa, International Consultants in Engineering, Architecture, Planning and Management, for the St. Paul District, Corps of Engineers.



LEGEND

3 INDEX NUMBER OF DETAIL SHEETS

STANDARD PROJECT FLOOD

5 CROSS SECTION

2 RIVER MILES

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

INDEX MAP - FLOODED AREA

ONTONAGON RIVER
ONTONAGON, MICHIGAN
SEPTEMBER 1970

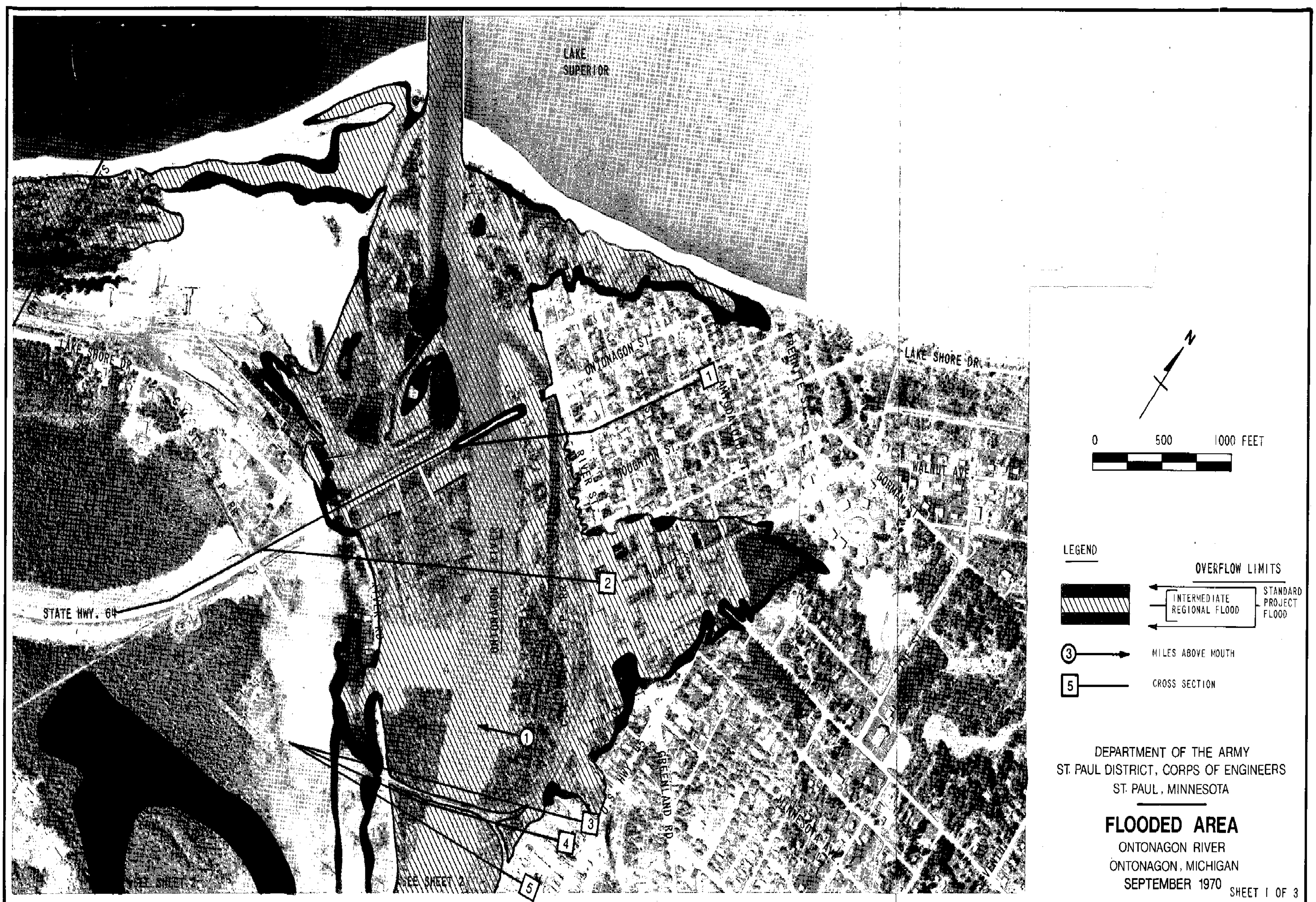
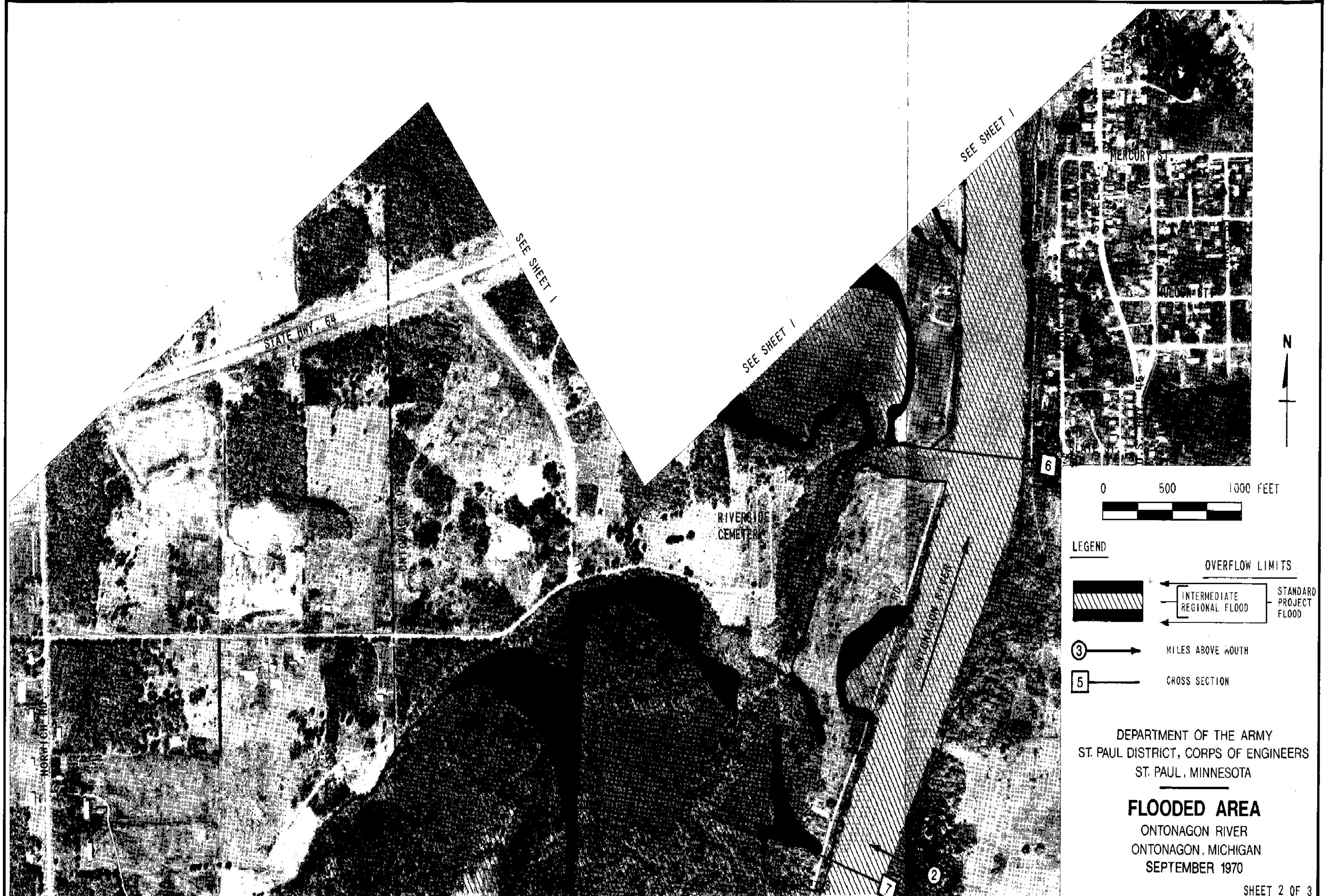

LAKE SUPERIOR
LAKE SHORE DR.
ONTONAGON ST.
HOUGHTON ST.
RIVER ST.
LAKE SHORE DR.
WALNUT AVE
GREENLAND RD.
STATE HWY. 64
SEE SHEET 2
0
500
1000 FEET
N
LEGEND
OVERFLOW LIMITS
INTERMEDIATE REGIONAL FLOOD
STANDARD PROJECT FLOOD
MILES ABOVE MOUTH
CROSS SECTION
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
FLOODED AREA
ONTONAGON RIVER
ONTONAGON, MICHIGAN
SEPTEMBER 1970
SHEET 1 OF 3

PLATE 9



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

FLOODED AREA
ONTONAGON RIVER
ONTONAGON, MICHIGAN
SEPTEMBER 1970

SHEET 2 OF 3

PLATE 10

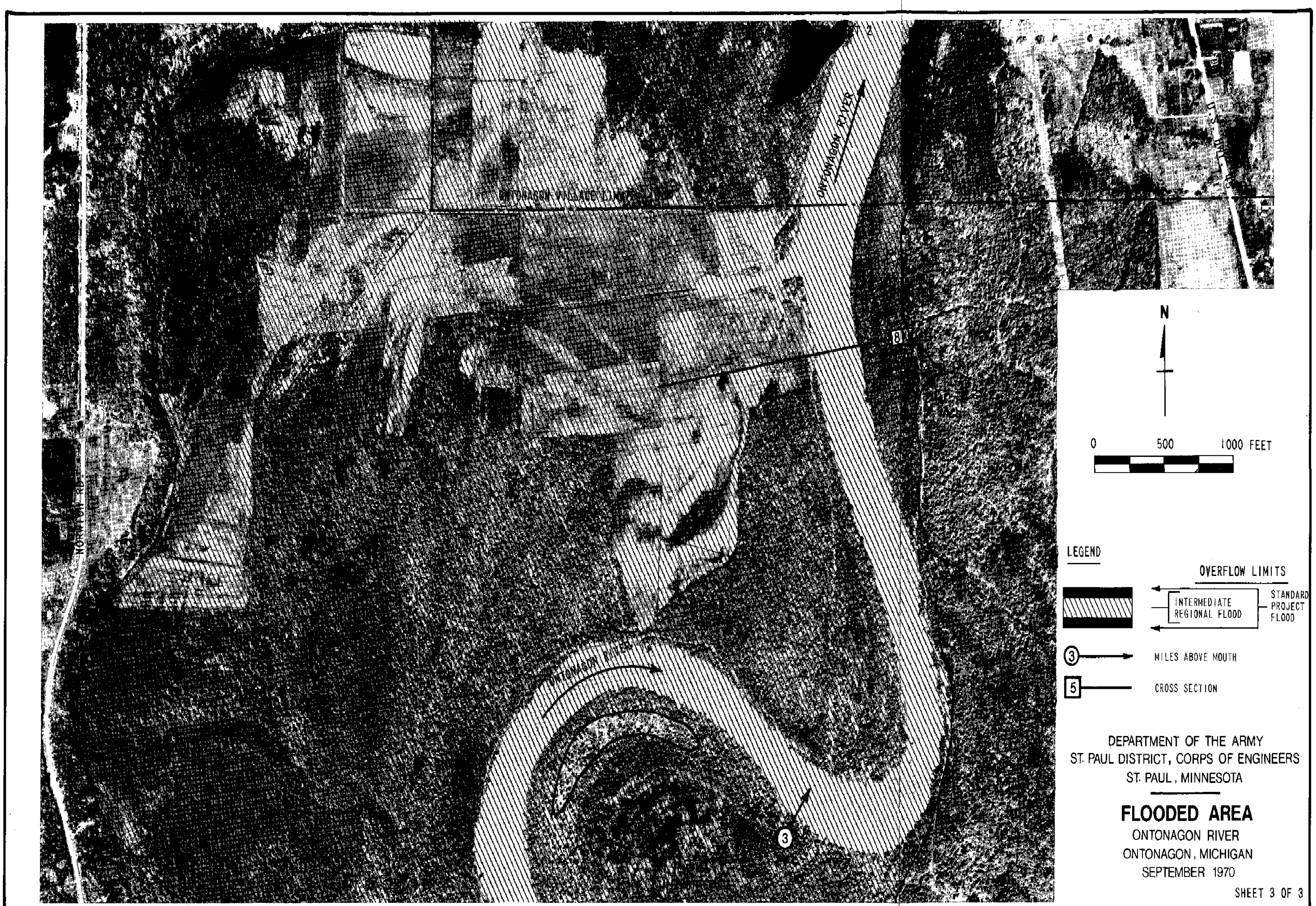
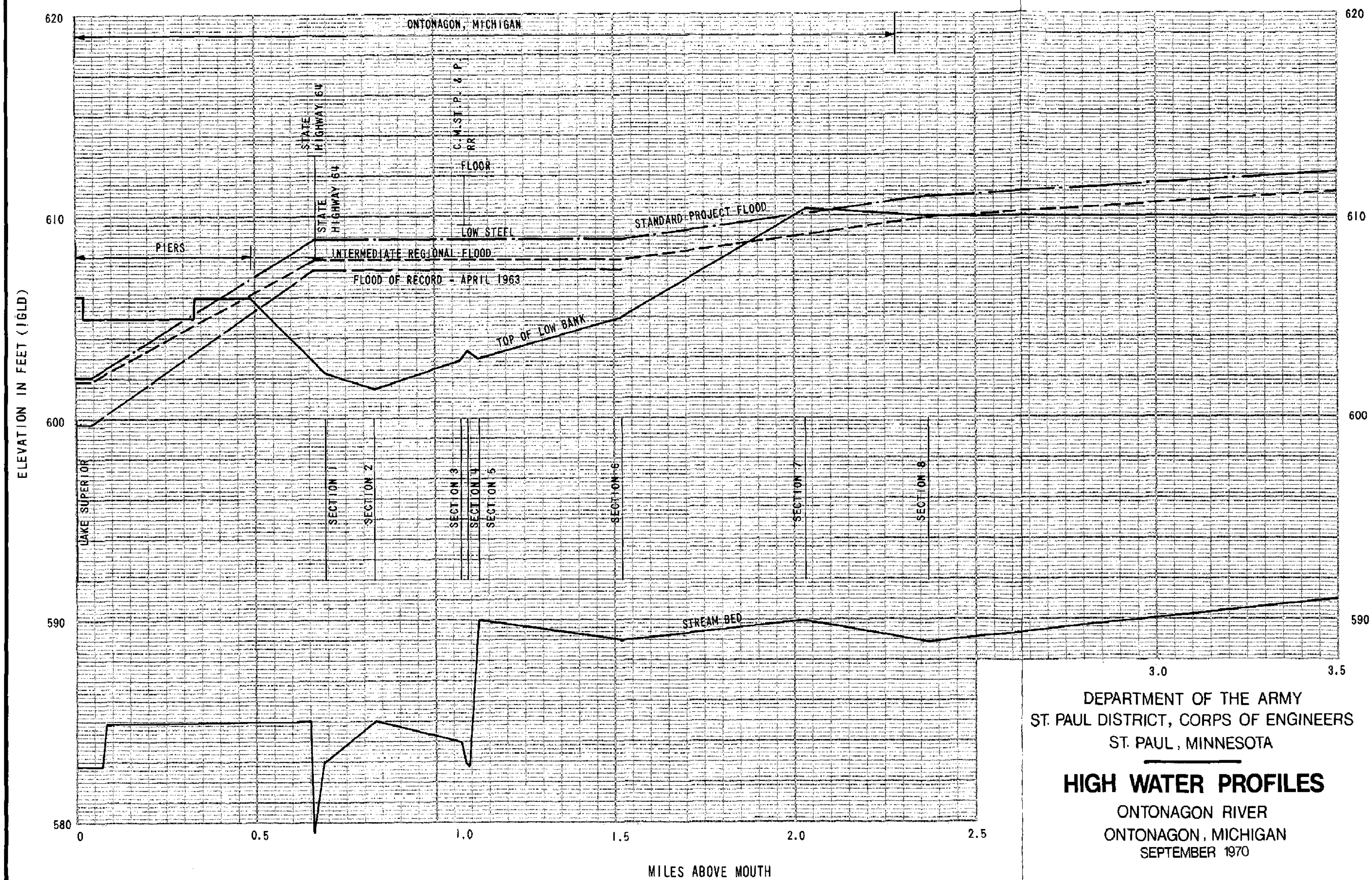

ONTONAGON RIVER
ONTONAGON VILLAGE LIMITS
NORWICH RD.
8
3
N
0
500
1000 FEET
LEGEND
OVERFLOW LIMITS
INTERMEDIATE REGIONAL FLOOD
STANDARD PROJECT FLOOD
MILES ABOVE MOUTH
CROSS SECTION
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
FLOODED AREA
ONTONAGON RIVER
ONTONAGON, MICHIGAN
SEPTEMBER 1970
SHEET 3 OF 3

PLATE 11

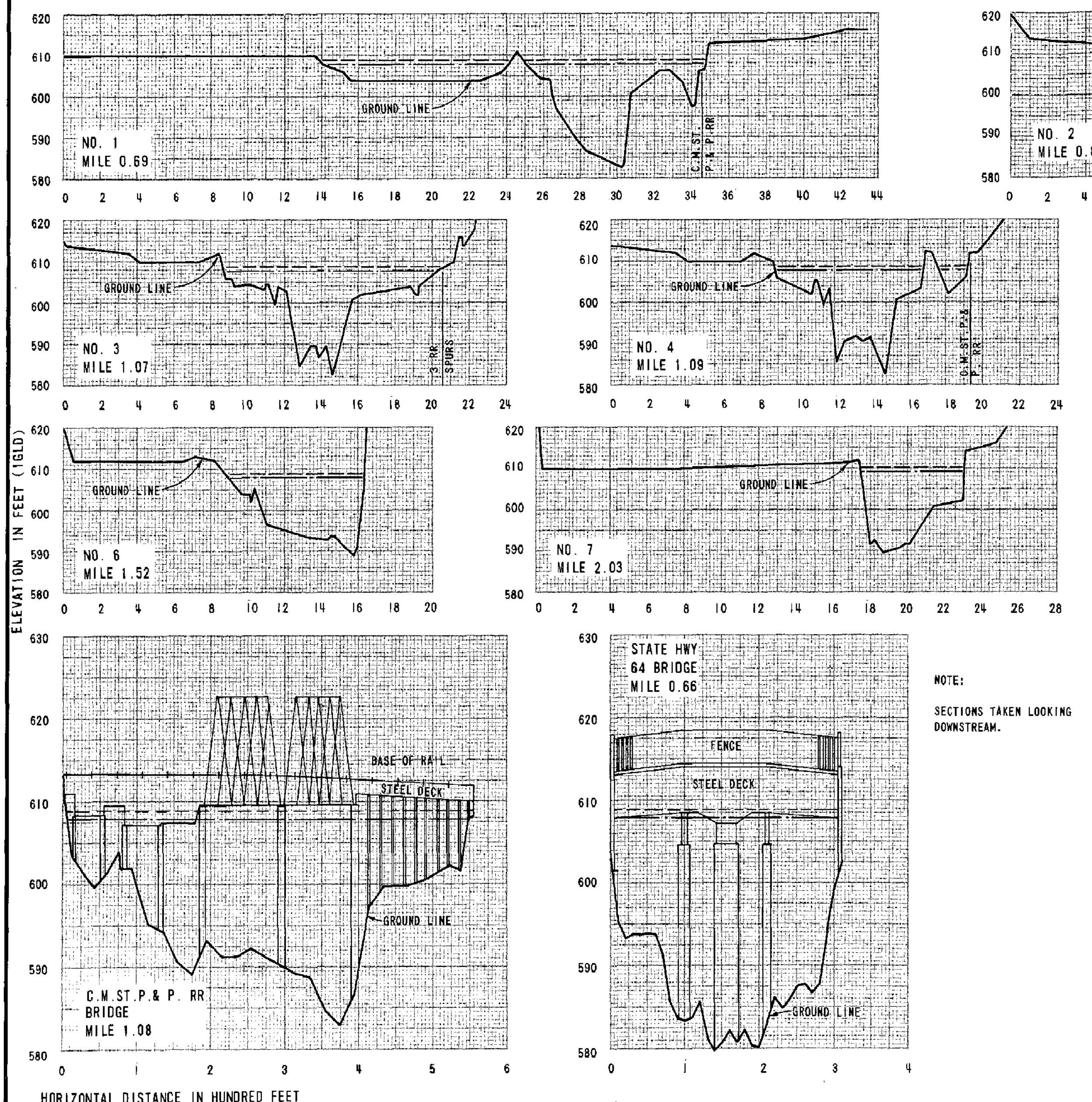


DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

HIGH WATER PROFILES

ONTONAGON RIVER
ONTONAGON, MICHIGAN
SEPTEMBER 1970

PLATE 12



NOTE:

SECTIONS TAKEN LOOKING DOWNSTREAM.

LEGEND:

— — — STANDARD PROJECT FLOOD

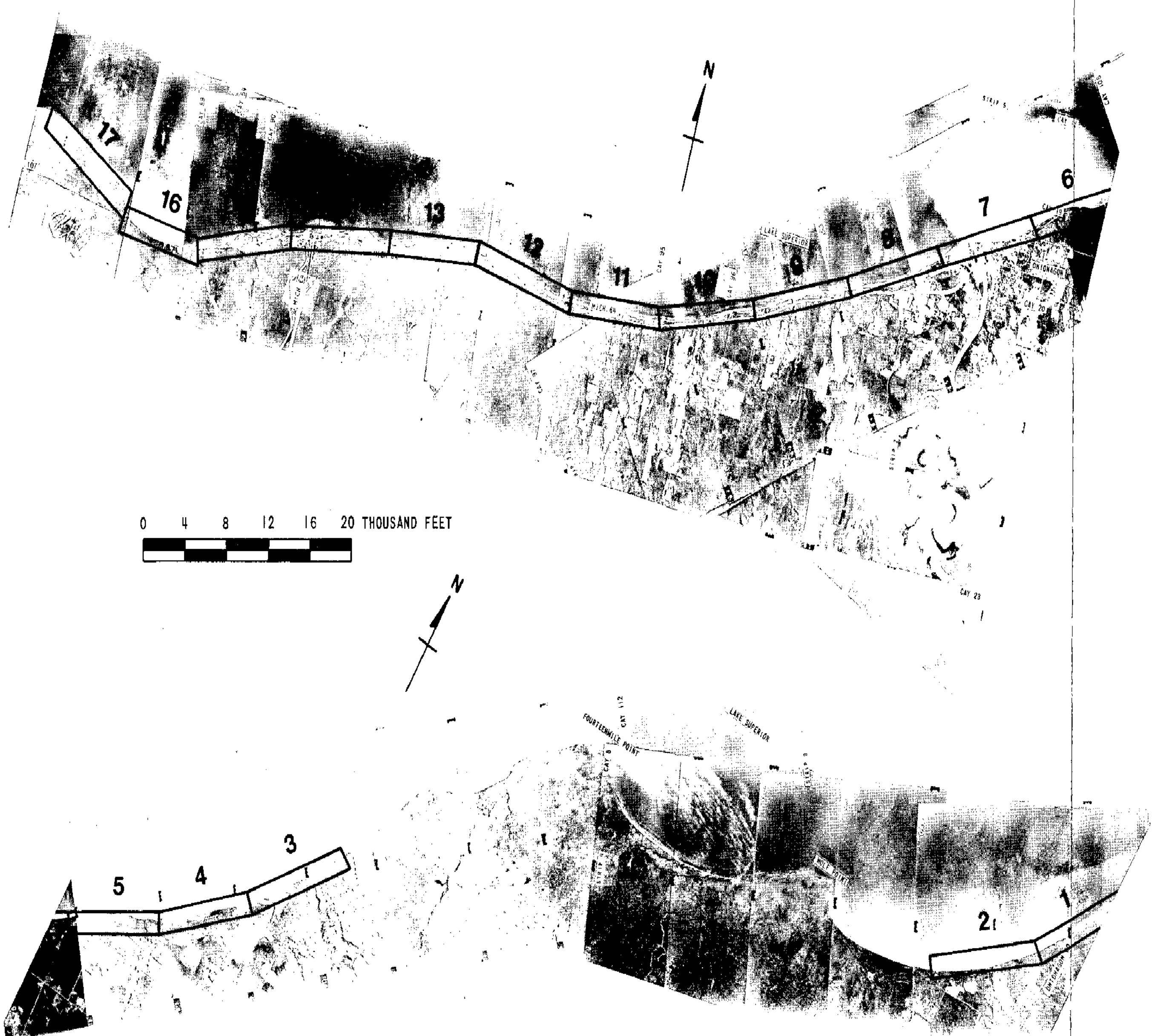
—·— INTERMEDIATE REGIONAL FLOOD

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

CROSS SECTIONS

ONTONAGON RIVER
ONTONAGON, MICHIGAN
SEPTEMBER 1970

PLATE 13



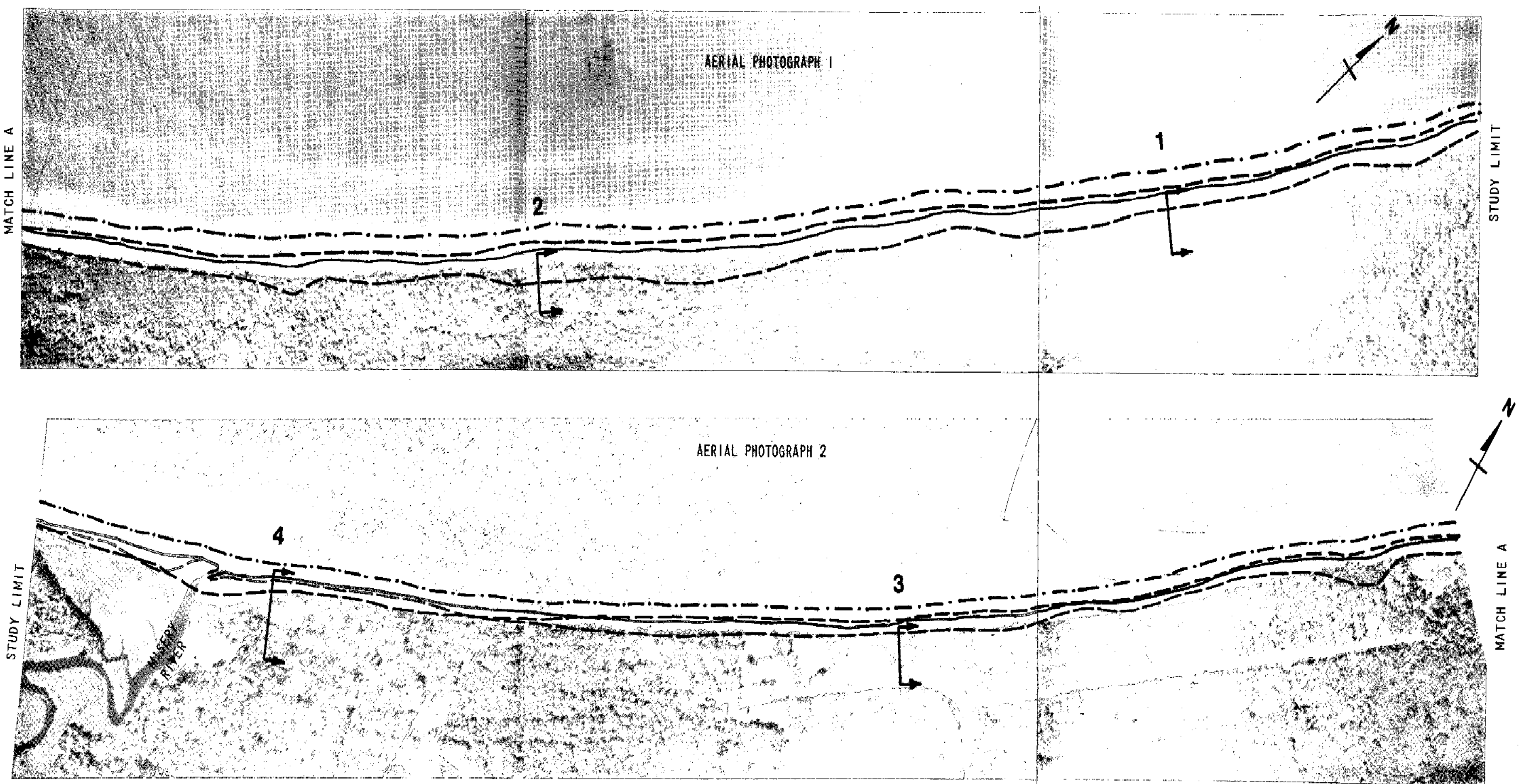
LEGEND

6 INDEX NUMBER OF AERIAL PHOTOGRAPHS

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

INDEX MAP - SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970



LEGEND

- SHORELINE IN 1860
- SHORELINE IN 1964
- SHORELINE IN 1970
- PROJECTED SHORELINE IN 2020
- 7 BEACH CROSS SECTIONS

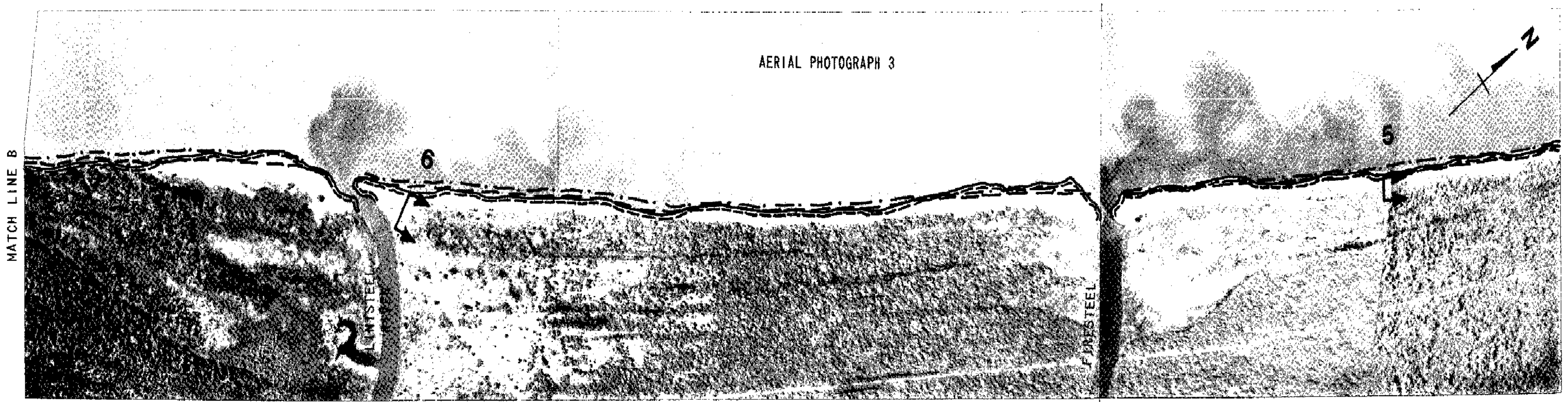
0 500 1000 1500 FEET

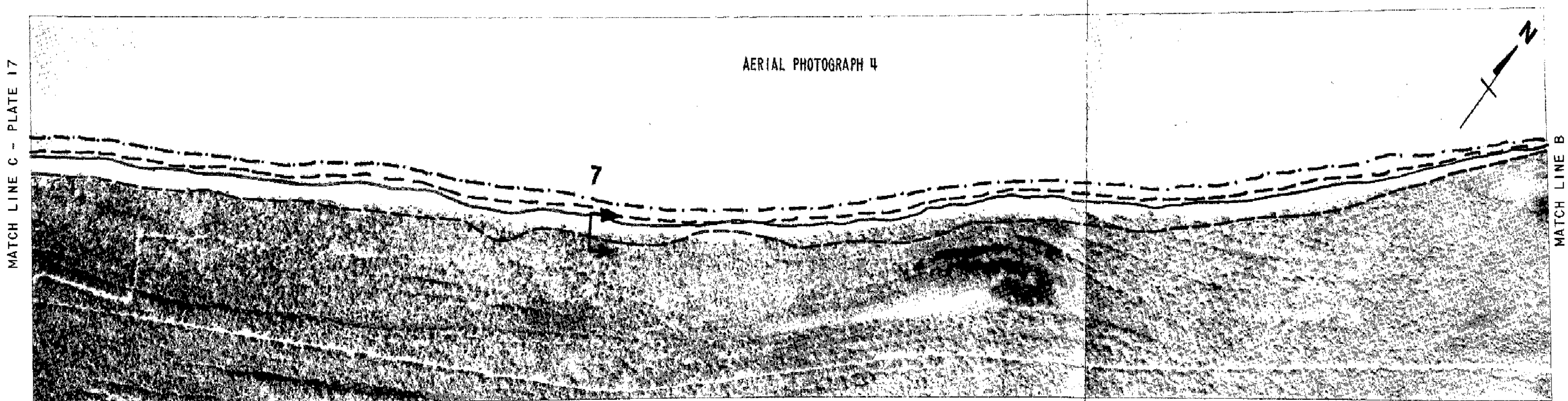
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

PLATE 15





LEGEND

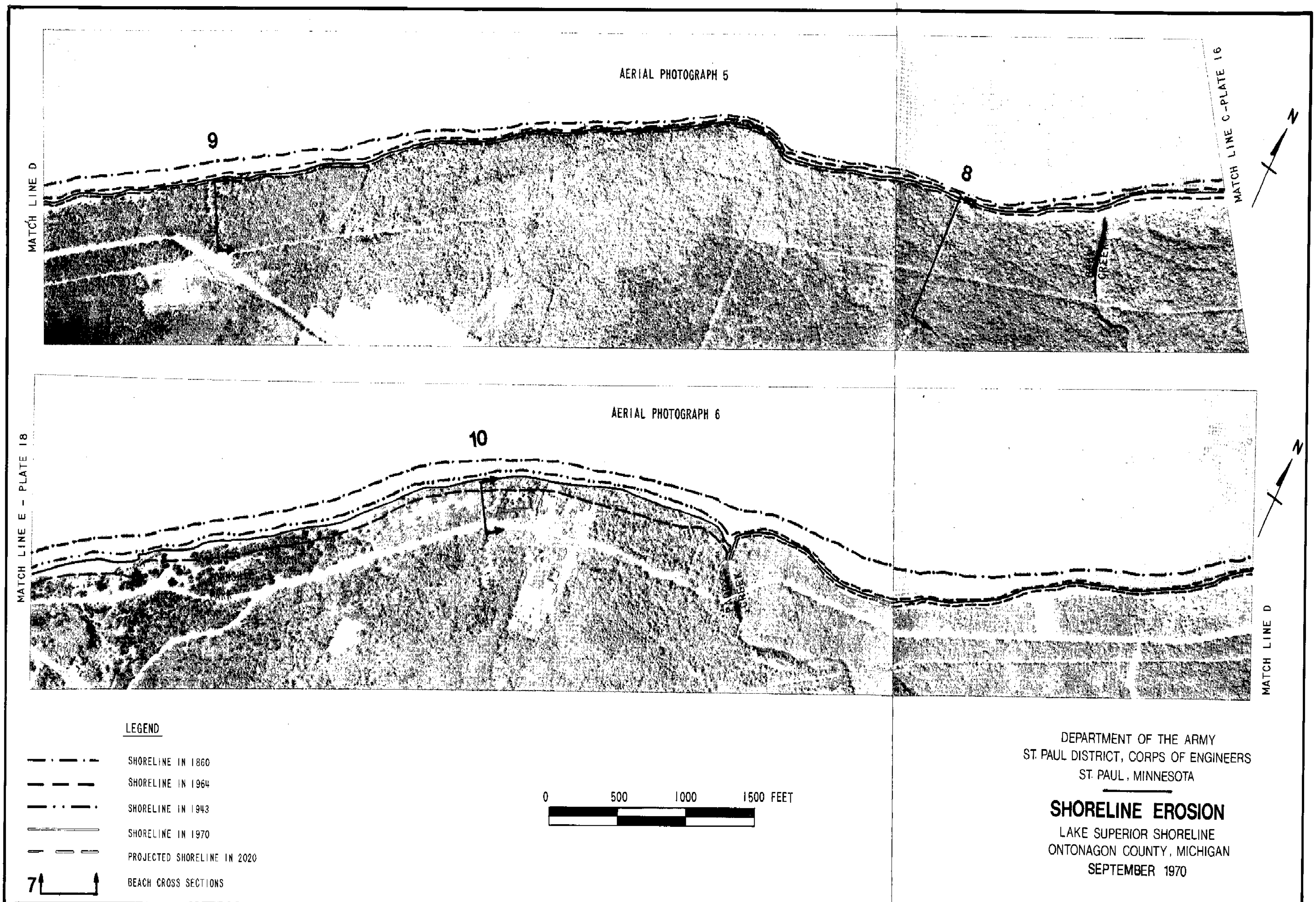
- SHORELINE IN 1860
- SHORELINE IN 1964
- SHORELINE IN 1970
- PROJECTED SHORELINE IN 2020
- 7 BEACH CROSS SECTIONS

0 500 1000 1500 FEET

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

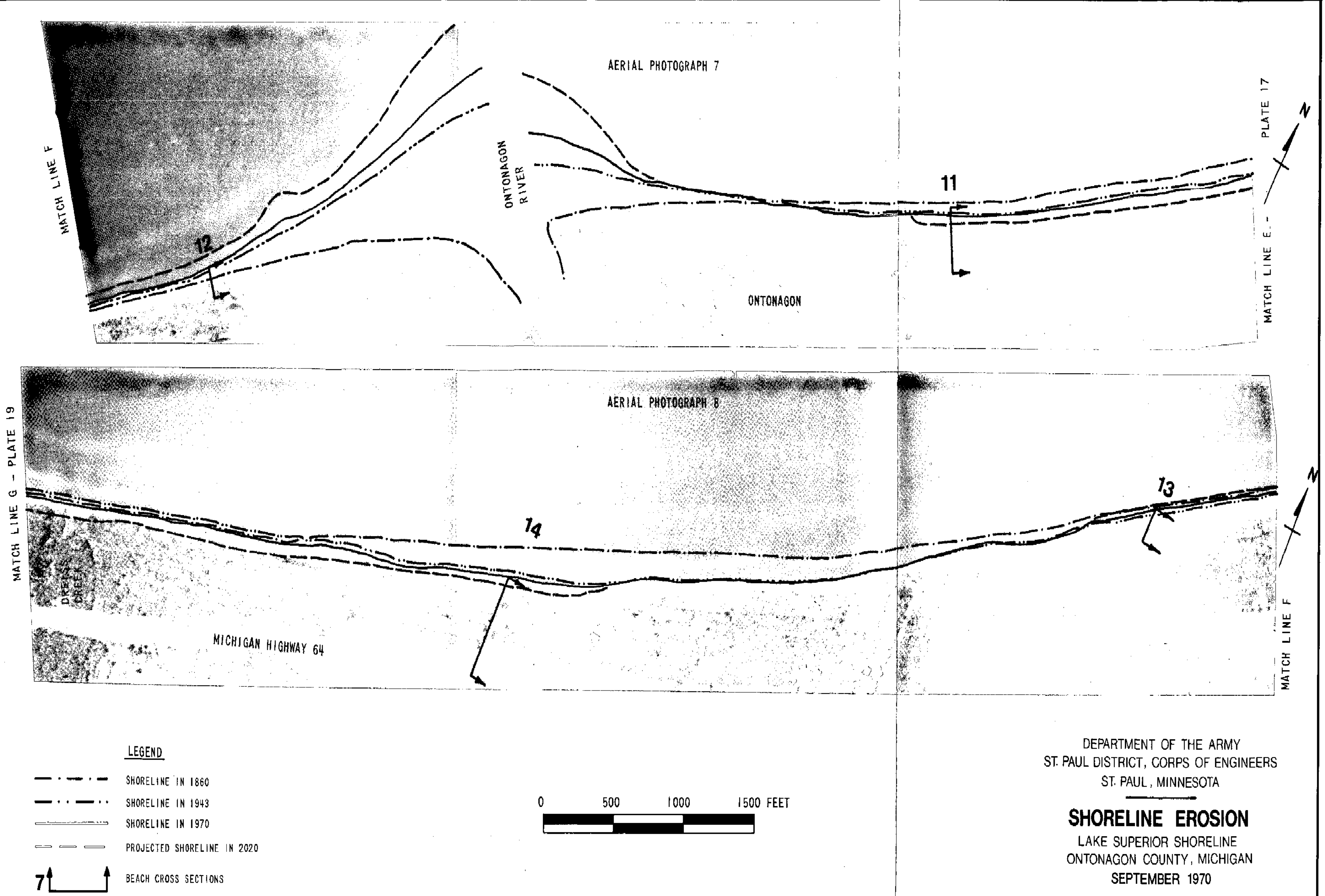


DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

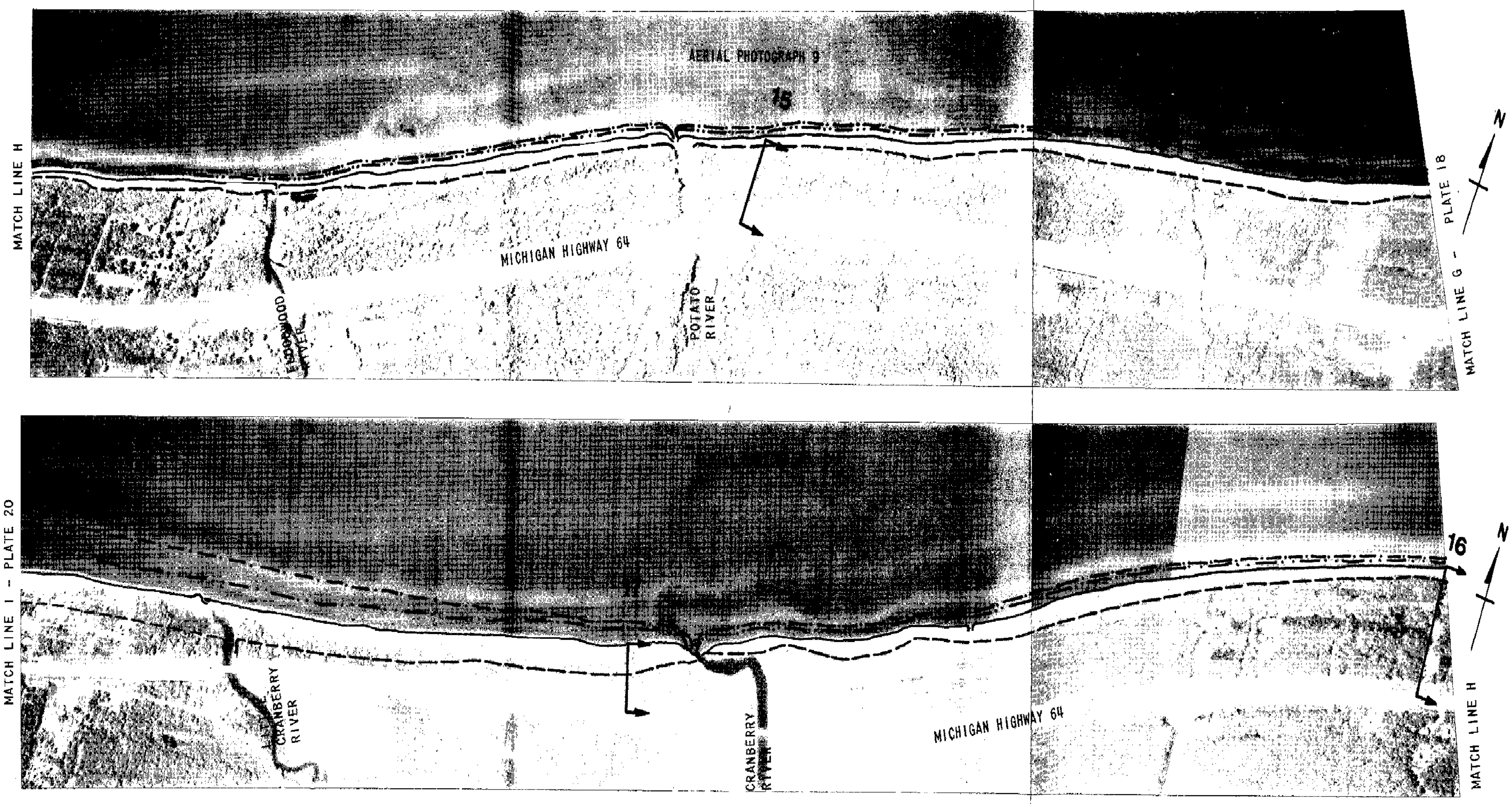
PLATE 17



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970



LEGEND

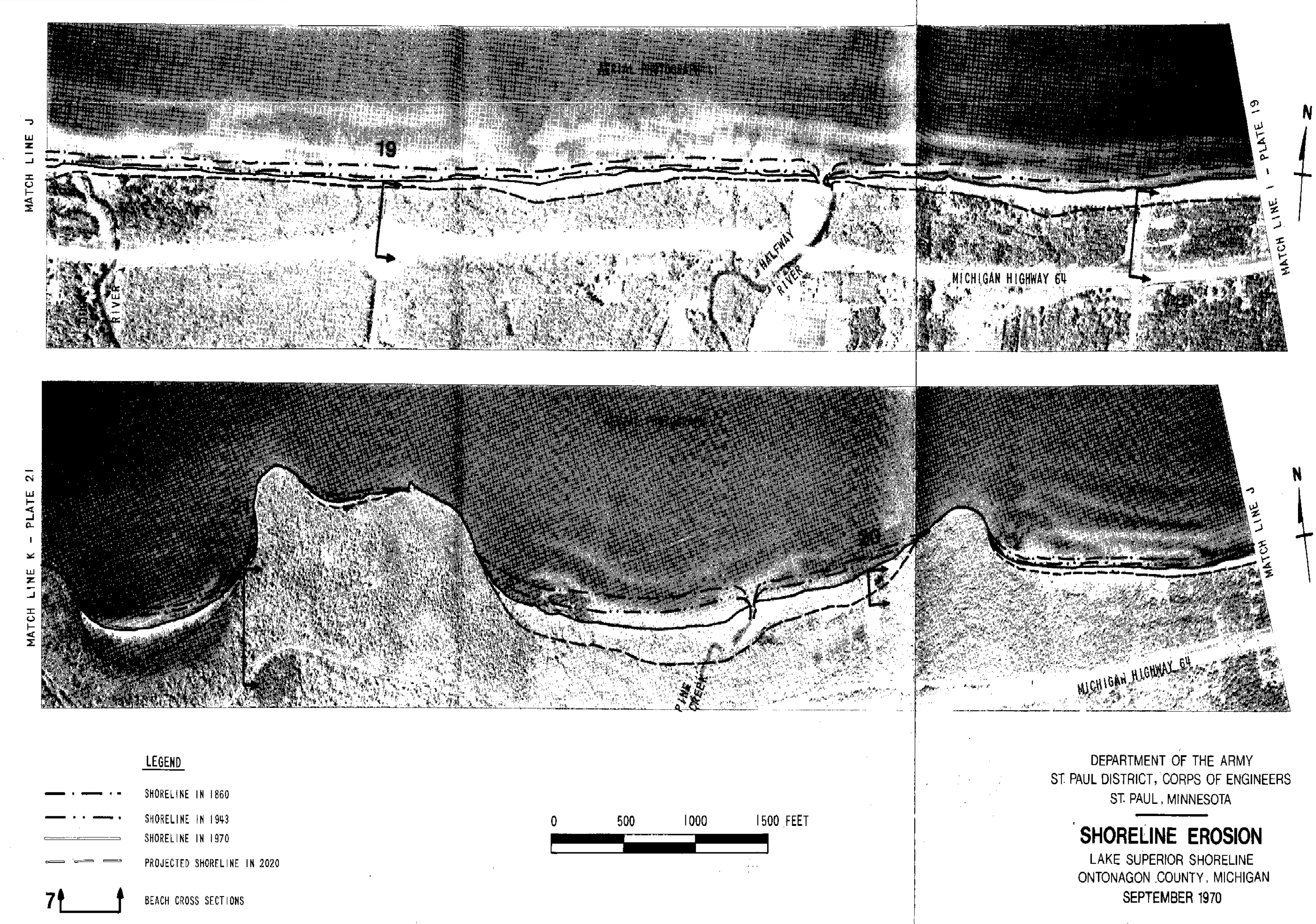
- SHORELINE IN 1860
- SHORELINE IN 1943
- SHORELINE IN 1970
- PROJECTED SHORELINE IN 2020
- 7 BEACH CROSS-SECTIONS

0 500 1000 1500 FEET

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

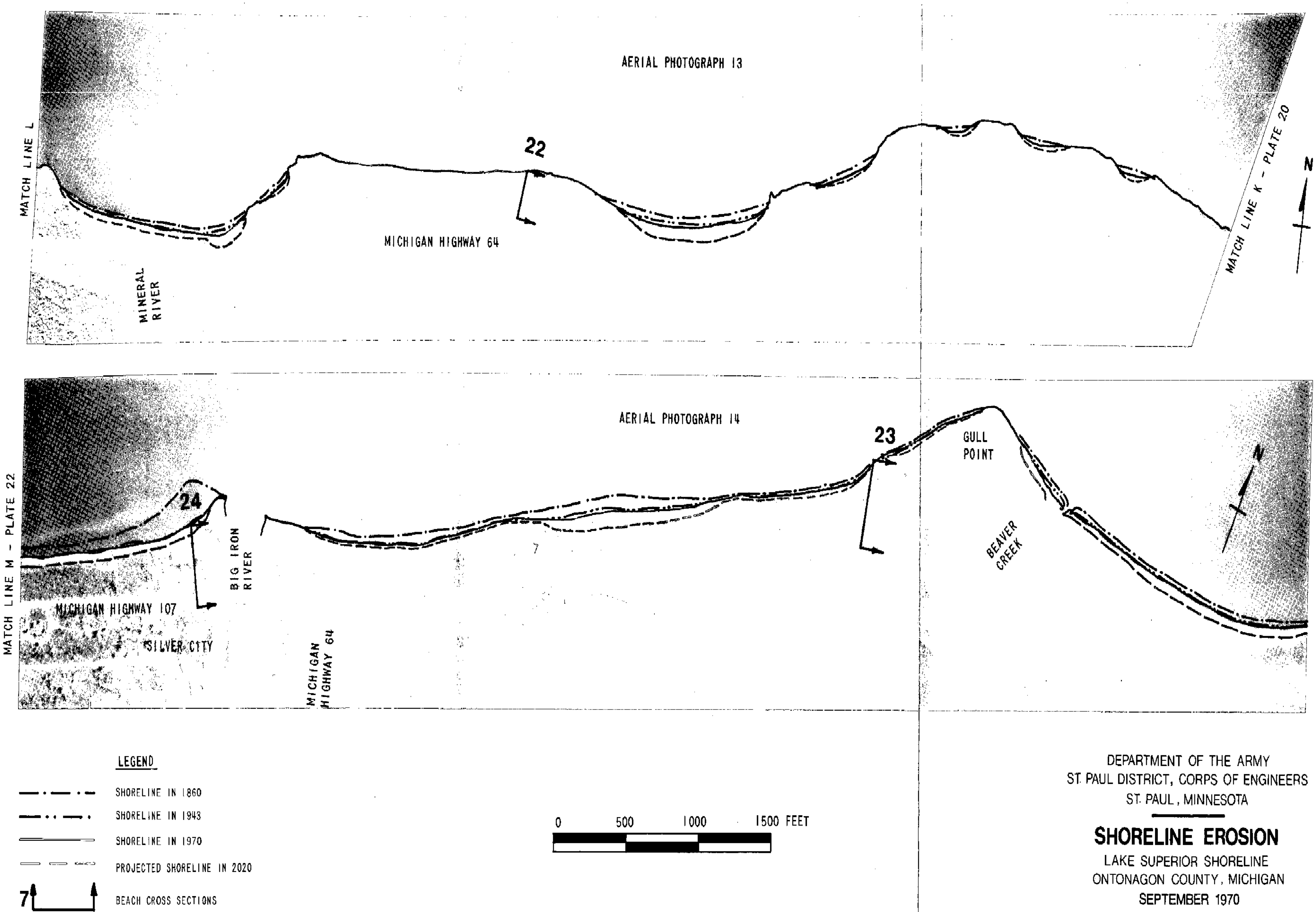


DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

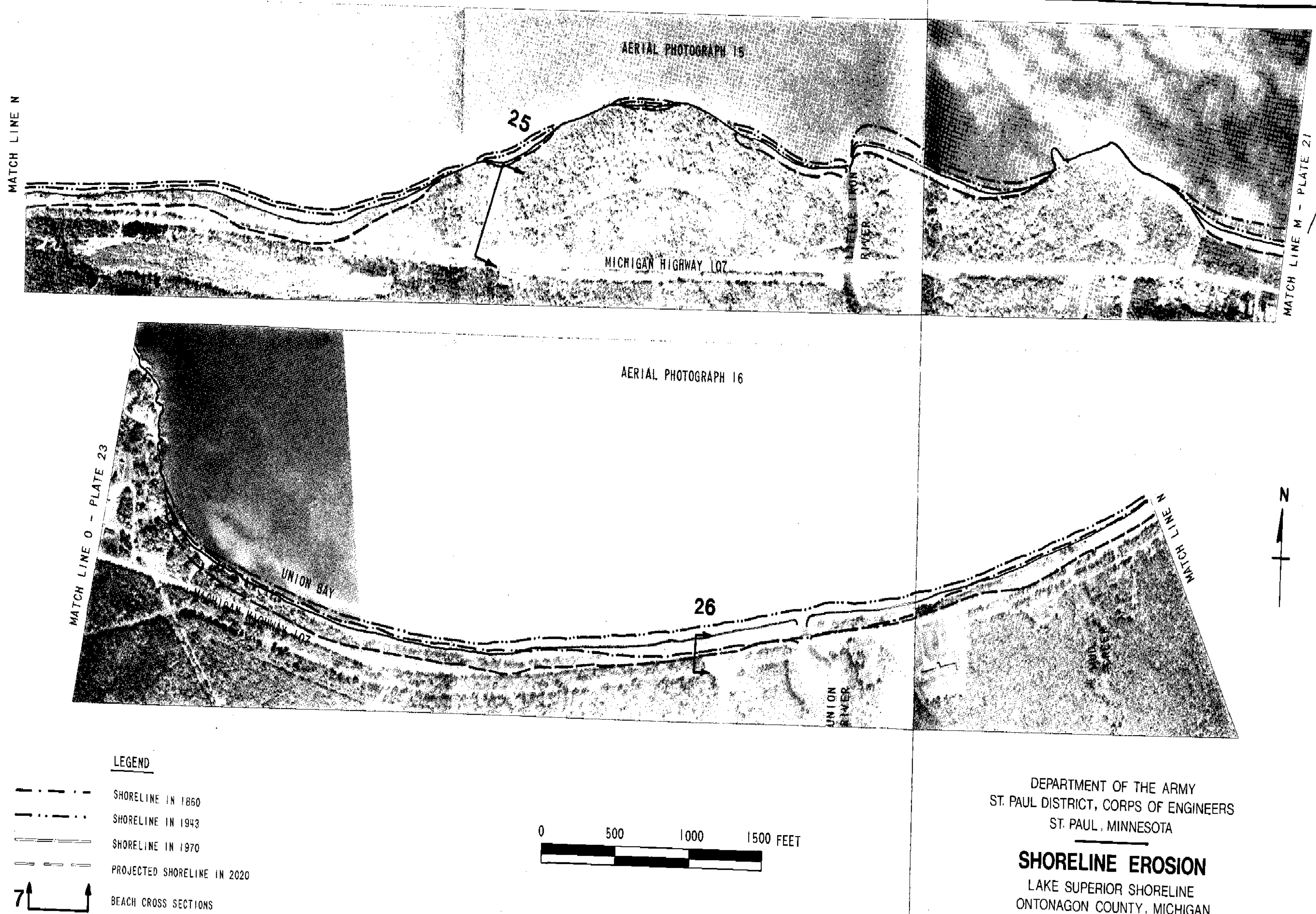
PLATE 20



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

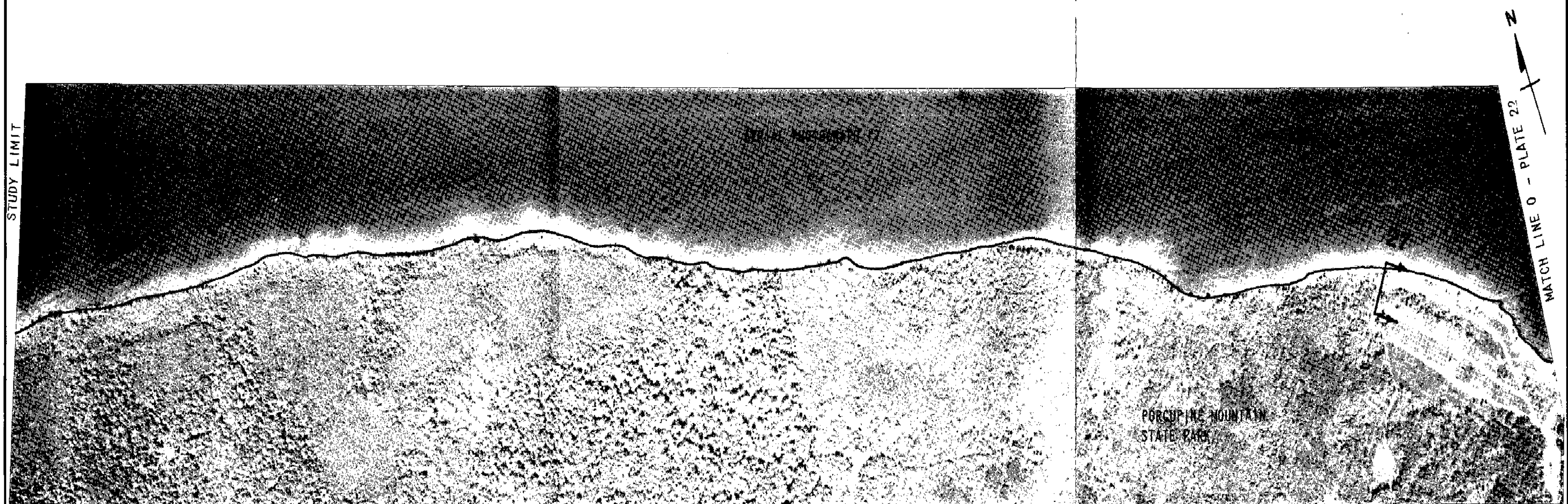


DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

PLATE 22



LEGEND

SHORELINE IN 1970

7 BEACH CROSS SECTIONS

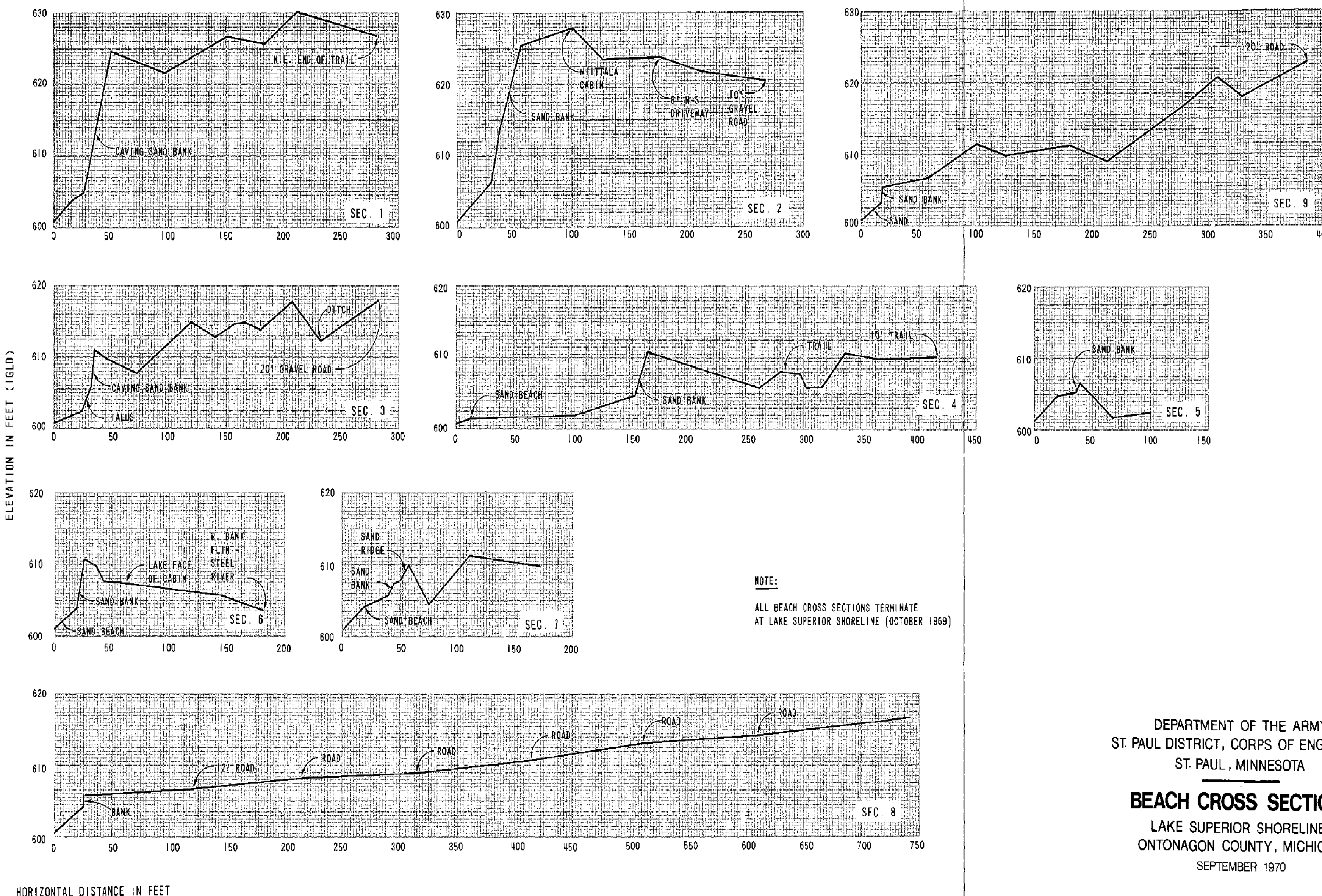
NOTE: THROUGHOUT THIS REACH NO EROSION HAS OCURRED FROM 1860 TO THE PRESENT AND NONE IS PROJECTED UP TO THE YEAR 2020.

0 500 1000 1500 FEET

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

SHORELINE EROSION

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970



NOTE:

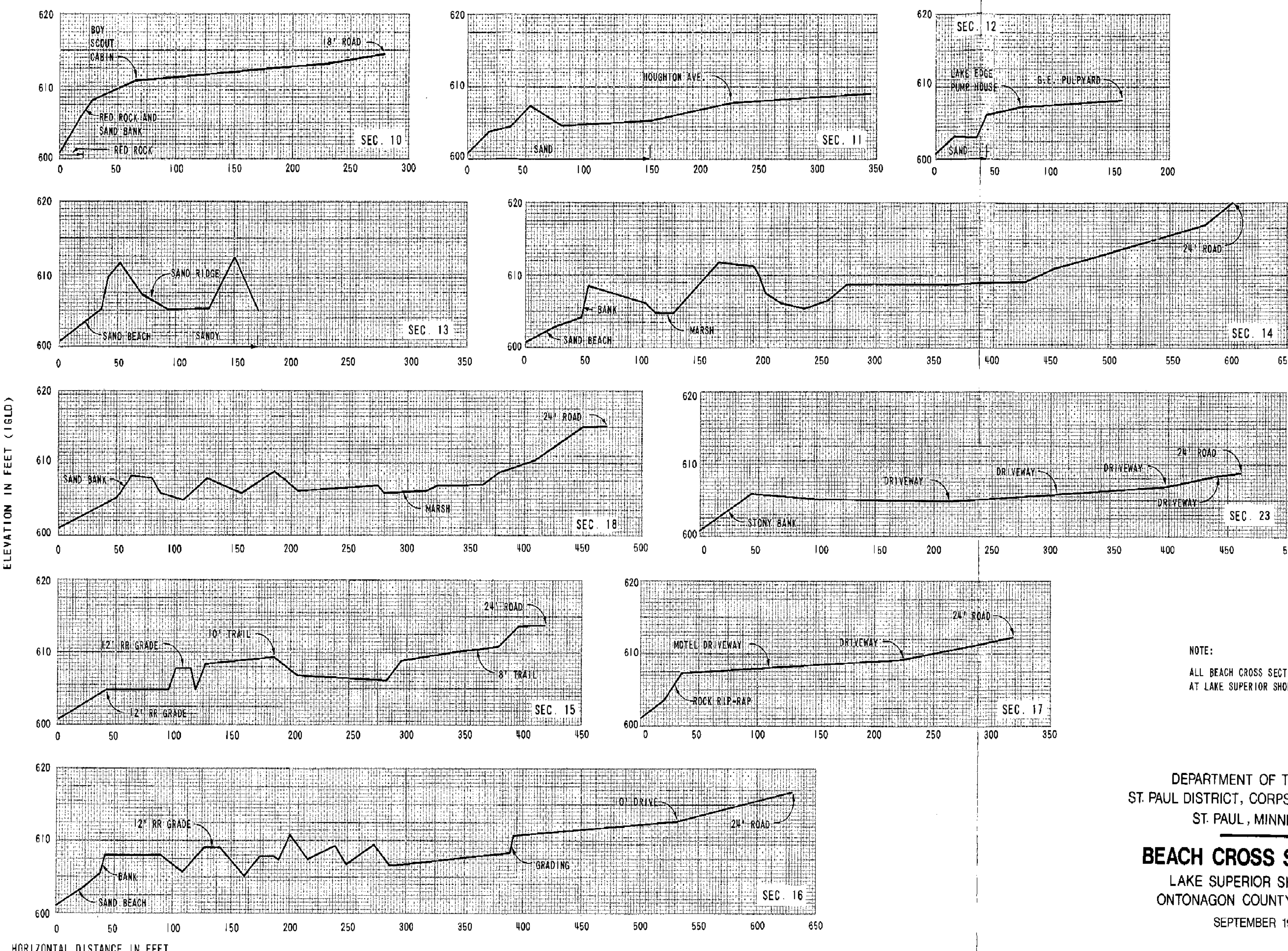
ALL BEACH CROSS SECTIONS TERMINATE
AT LAKE SUPERIOR SHORELINE (OCTOBER 1969)

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

BEACH CROSS SECTIONS

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970

PLATE 24



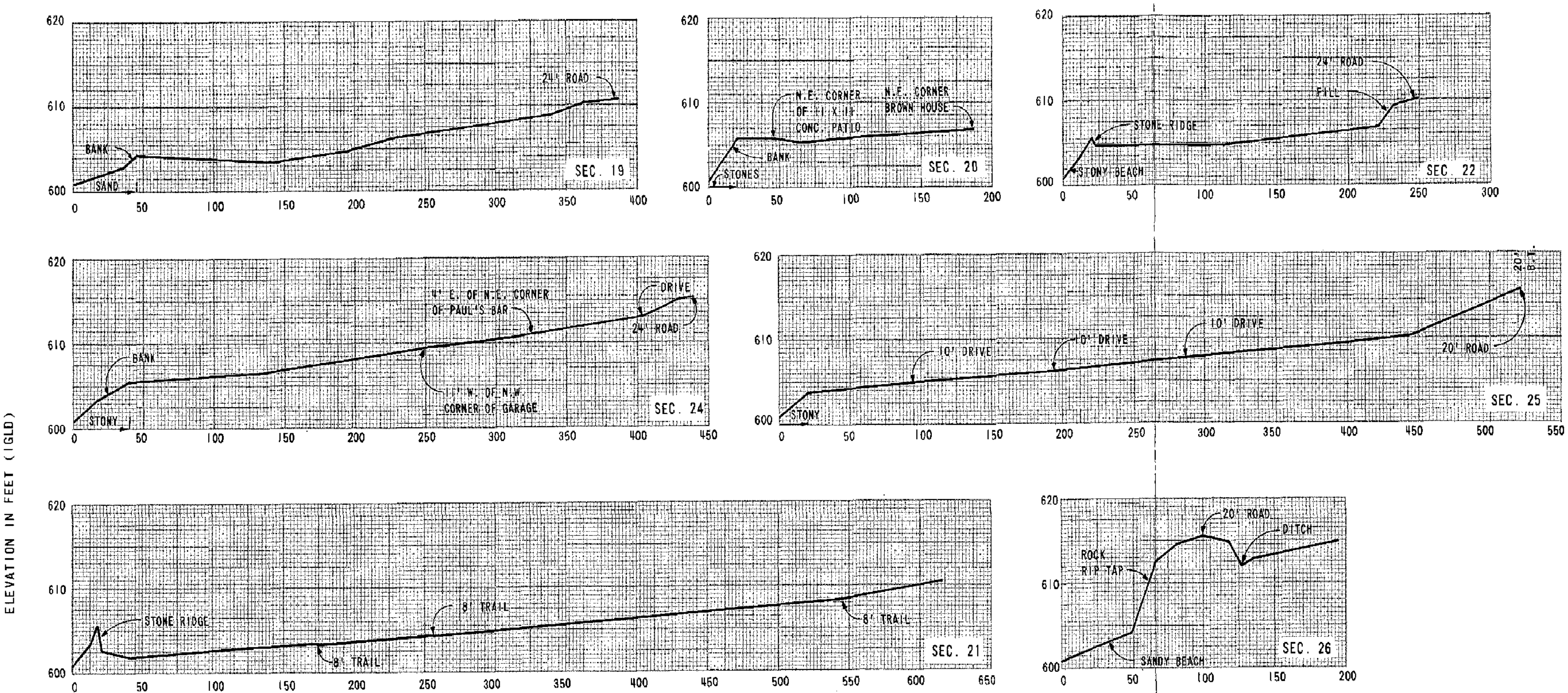
NOTE:

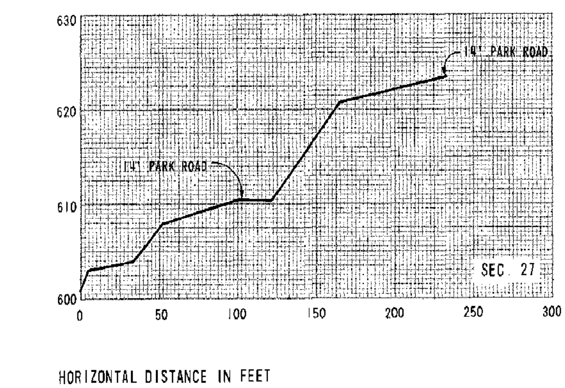
ALL BEACH CROSS SECTIONS TERMINATE AT LAKE SUPERIOR SHORELINE (OCTOBER 1969).

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

BEACH CROSS SECTIONS

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN
SEPTEMBER 1970





NOTE:

ALL BEACH CROSS SECTIONS TERMINATE AT LAKE SUPERIOR SHORELINE (OCTOBER 1969).

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

BEACH CROSS SECTIONS

LAKE SUPERIOR SHORELINE
ONTONAGON COUNTY, MICHIGAN

SEPTEMBER 1970